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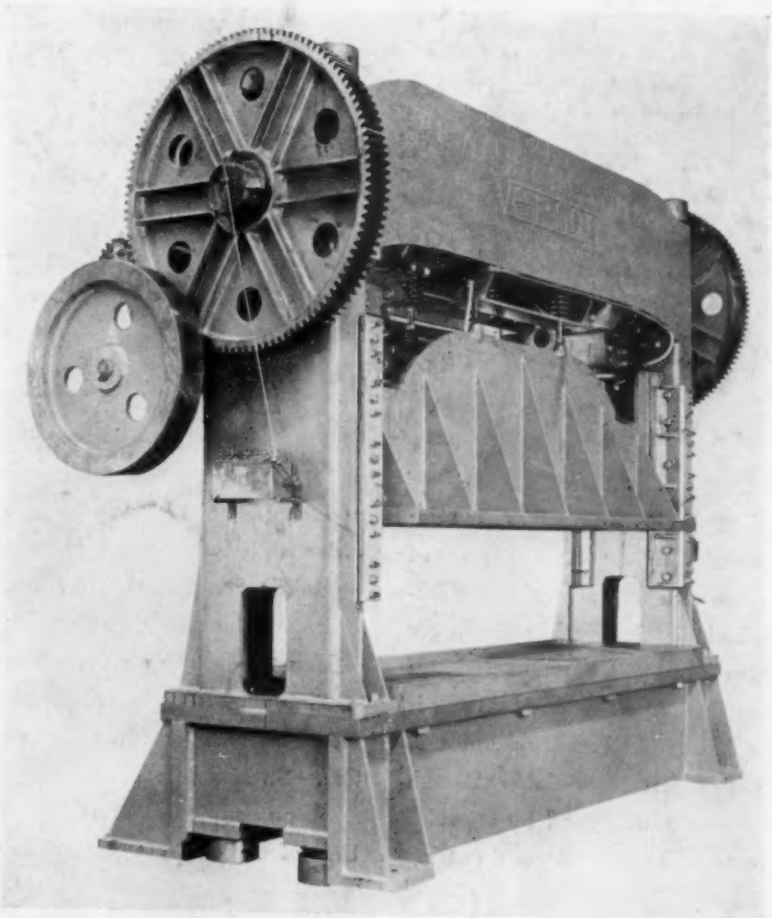
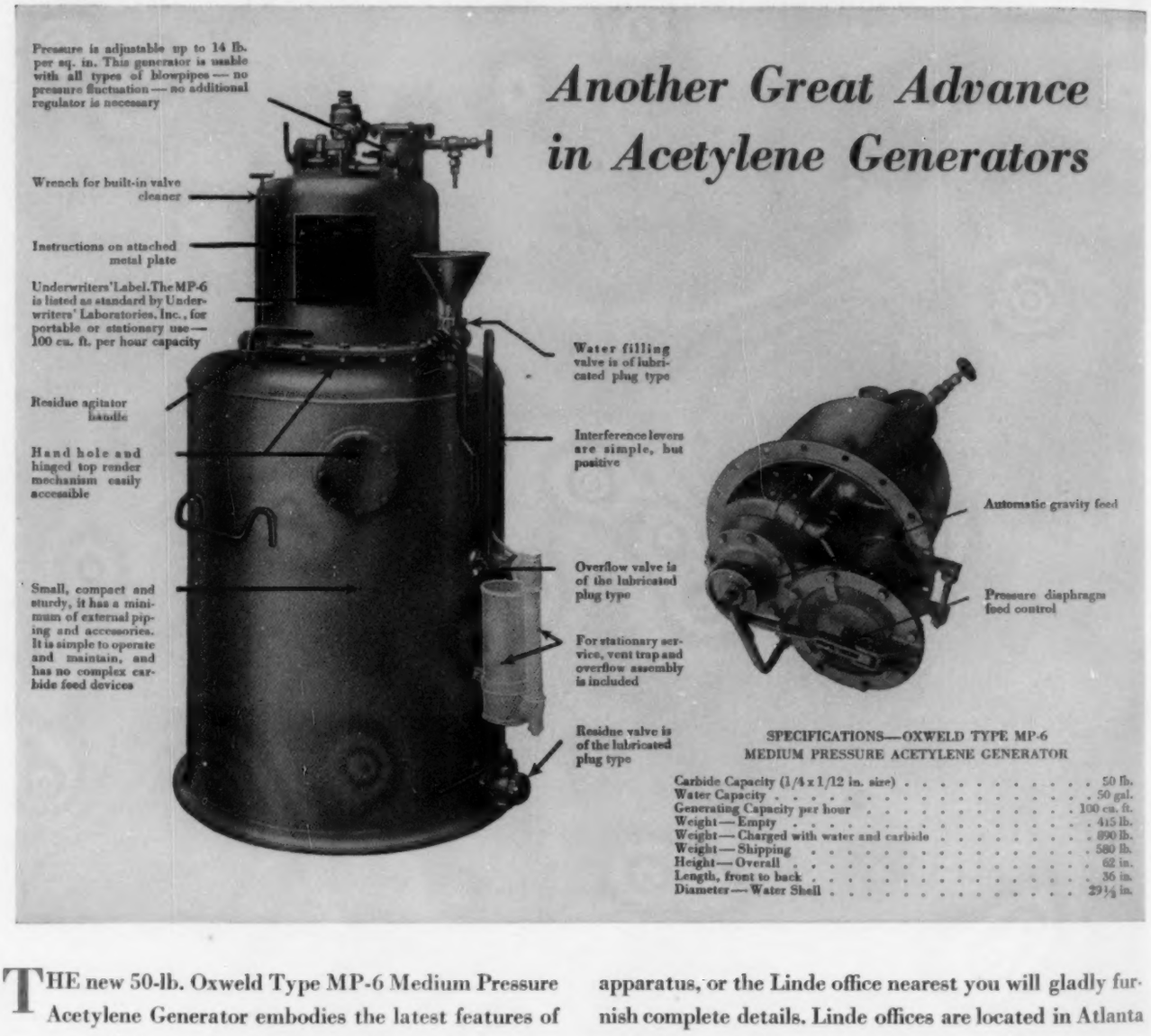


PUBLISHED MONTHLY FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

THE NEW OXWELD MP-6


Another Great Advance in Acetylene Generators
Pressure is adjustable up to 14 lb. per sq. in. This generator is usable with all types of blowpipes — no pressure fluctuation — no additional regulator is necessary
Wrench for built-in valve cleaner
Instructions on attached metal plate
Underwriters' Label. The MP-6 is listed as standard by Underwriters' Laboratories, Inc., for portable or stationary use — 100 cu. ft. per hour capacity
Residue agitator handle
Hand hole and hinged top render mechanism easily accessible
Small, compact and sturdy, it has a minimum of external piping and accessories. It is simple to operate and maintain, and has no complex carbide feed devices
Water filling valve is of lubricated plug type
Interference levers are simple, but positive
Overflow valve is of the lubricated plug type
For stationary service, vent trap and overflow assembly is included
Residue valve is of the lubricated plug type
Automatic gravity feed
Pressure diaphragm feed control
SPECIFICATIONS—OXWELD TYPE MP-6
MEDIUM PRESSURE ACETYLENE GENERATOR
Carbide Capacity (1/4 x 1/12 in. size) . . . 50 lb.
Water Capacity . . . 50 gal.
Generating Capacity per hour . . . 100 cu. ft.
Weight — Empty . . . 415 lb.
Weight — Charged with water and carbide . . . 890 lb.
Weight — Shipping . . . 580 lb.
Height — Overall . . . 62 in.
Length, front to back . . . 36 in.
Diameter — Water Shell . . . 29½ in.

THE new 50-lb. Oxweld Type MP-6 Medium Pressure Acetylene Generator embodies the latest features of generator design and construction. Many of these features were never before included in any but the larger sizes of Oxweld Generators. Study the unusual things about the MP-6 illustrated above. Notice how well it is built for maximum efficiency in handling and use.

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THE
AMERICAN WELDING SOCIETY
JOURNAL

WM. SPRARAGEN, Editor | VOL. 14 | NO. 7

JULY

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New Welded Steel Bulkhead System for Oil Tankers and Other Fluid Storage Vessels

By G. D. SPACKMAN†

A NEW type of bulkhead system for fluid storage on oil tankers and other vessels handling fluids have been developed by Lukens Steel Company and its division, Lukenweld, Inc., Coatesville, Pa.

The complete bulkhead system is composed of a series of pressed steel plates, integrated by welding. Each pressed plate combines two elements, an ellipitcal bulge, and one-half of a channel-shaped member, as shown in Figs. 1 and 2. The channel-shaped member is completed when two pressed plates are welded together as shown in Fig. 3. Figure 1 illustrates the appearance of one of the pressed steel buckle plates when split center longitudinally, while Fig. 2 shows the appearance of one buckle plate when split vertically, and Fig. 3 demonstrates how four of the buckle plates are joined to form transverse channels.

The elliptical bulge is the proper shape for receiving the fluid pressure. It transmits its share of the fluid pressure load to the vertical webs by a complicated form of hoop tension. The channel transmits a share of the fluid pressure load to the same vertical web and preserves the transverse continuity essential for whatever diaphragming action may be necessary.

Compared with a conventional riveted bulkhead in a tanker with 66 ft. beam and 38 ft. molded depth with

† President, Lukenweld, Inc., division of Lukens Steel Company.

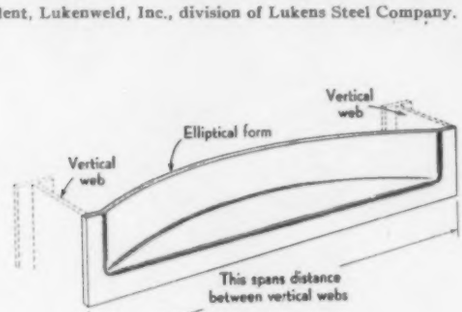


Fig. 1

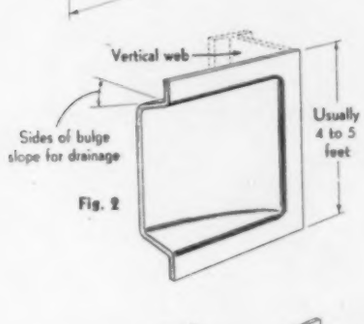


Fig. 2

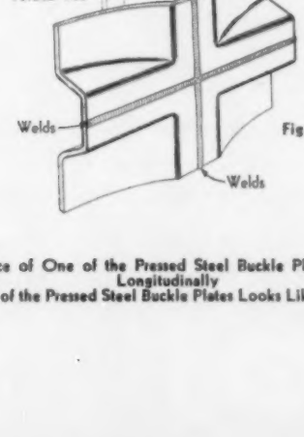


Fig. 3

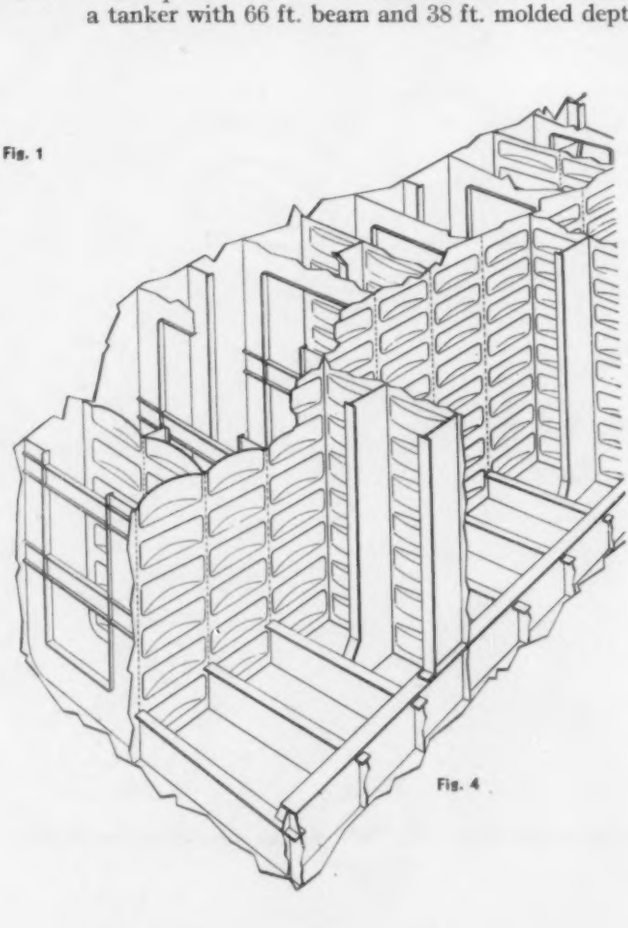


Fig. 4

Fig. 1—Appearance of One of the Pressed Steel Buckle Plates When Split Center Longitudinally

Fig. 2—What One of the Pressed Steel Buckle Plates Looks Like When Split Vertically

Fig. 3—How Four of the Pressed Steel Buckle Plates Are Joined to Form Transverse Channels

Fig. 4—Schematic Drawing Showing General Arrangement of Proposed Bulkhead System in an Oil Tanker

COMPARISON OF CONVENTIONALLY-STIFFENED BULKHEADS, RIVETED AND WELDED, AND WELDED BUCKLE PLATE BULKHEADS

	TYPE	BEAM	Molded Depth	Thickness of Plate	Area Square Feet	WEIGHT LBS. Total	WEIGHT LBS. Per Sq. Ft.	WEIGHT LBS. Ratio	STIFFENING Total Area Sq. Ft.	STIFFENING Area Per Sq. Ft. B'd.	STIFFENING Ratio
1	Conv. Rivet "A"	65'-9"	37'-0"	25/32" Top 5/8" 9/16" 1/2"	2451	112,800	46.0	140%	4560	1.86	139%
2	Conv. Welded "A"	65'-9"	37'-0"	25/32" Top 5/8" 9/16" 1/2"	2451	92,410	37.7	115%	4560	1.86	139%
3	Conv. Rivet "B"	65'-9"	37'-0"	25/32" Top 5/8" 9/16" 1/2"	2469	110,140	44.6	136%	4730	1.92	143%
4	Conv. Welded "B"	65'-9"	37'-0"	25/32" Top 5/8" 9/16" 1/2"	2469	88,910	36.0	109%	4730	1.92	143%
5	Buckle Pl. Weld. "B"	74'-0"	40'-0"	25/32" Top 5/8" 9/16"	2962	97,200	32.8	100%	3760	1.27	95%
6	Buckle Pl. Weld. "B"	68'-0"	38'-0"	25/32" Top 5/8" 9/16"	2596	85,560	32.9	100%	3470	1.34	100%

"A"—WITH CENTER LINE LONGITUDINAL BULKHEAD AND EXPANSION TRUNK.
"B"—TWO LONGITUDINAL BULKHEADS.

	NO. PARTS Total	NO. PARTS Per Sq. Ft. of B'd.	NO. PARTS Ratio	*By Shipbuilder TOTAL WELDING Length	TOTAL WELDING Length Per Sq. Ft.	TOTAL WELDING Ratio	WELDED BY SHIPBUILDER Length	WELDED BY SHIPBUILDER Length Per Sq. Ft.	WELDED BY SHIPBUILDER Ratio
1	338	.138	639%	----	----	----	----	----	----
2	152	.062	288%	4260'	1.74'	176%	4260'	1.74'	201%
3	283	.115	533%	----	----	----	----	----	----
4	143	.058	269%	4210'	1.70'	172%	4210'	1.70'	197%
5	105 *56	*.019	* 88%	2840'	.96'	97%	2420'	.82'	95%
6	97 *56	*.022	*100%	2580'	.99'	100%	2250'	.865'	100%

Fig. 5

two longitudinal bulkheads, this proposed bulkhead system will save about 25,000 lb. of weight, equivalent to a reduction of 26% in bulkhead weight.

The cost of this proposed bulkhead system closely approaches, and may be less than, the cost of conventional riveted bulkhead systems. Exact cost per ship depends on the number of dies required to produce the sizes of pressed plates the naval architect chooses to employ.

Figure 4 is a schematic drawing showing the general arrangement of the proposed bulkhead system in an oil tanker.

Ships at sea constantly undergo flexing, both torsional and bending. The moments from this flexing concentrate in general at the joints or junction of the component members. The semi-rigidness of a riveted joint, under the action of these forces, results in a great deal of working. In oil-tight tankers, this loosening up and resultant leakage necessitate continual caulking.

Properly designed and properly made welded joints result in a structure, the action of which is indistinguishable from that of a single piece of metal. Hence, there can be no leaks due to the working of a ship in a sea, provided the design and execution of the structure are such that the plates do not actually separate or fracture. It is these facts that make the welded bulkhead attractive for oil tankers.

Heretofore, the typical bulkhead has really consisted of two parts—that separating the two adjacent compartments and that which stiffens the first and makes it capable of resisting water pressure on one side. The proposed construction combines in largest degree these two functions. Thus, all the usual separate horizontal stiffeners are eliminated and the lateral stiffness is preserved by the integral channels.

The buckles are pressed by dies in individual plates. After trimming to size, as many buckle plates are shop welded as is convenient for shipment to the shipyard.

Figure 5 summarizes pertinent figures pertaining to certain transverse bulkheads of various constructions. Nos. 1, 3, 5 and 6 have been approved by the American Bureau of Shipping. The first two are riveted construction and the latter two welded. Nos. 2 and 4 are derived from Nos. 1 and 3 by omitting the butts and seams of the plating, the bounding angles of the bulkhead and of web stiffeners, and the bulkhead flanges of all directly connected stiffeners, thus reducing the riveted bulkheads to equivalent welded bulkheads.

Nos. 1 and 2 are for ships with a center line bulkhead and summer tanks. The others are for the two longitudinal bulkhead type of construction.

From riveted to welded construction as exemplified from No. 1 to No. 2 and from No. 3 to No. 4, there is a reduction in weight per square foot of 18% and 19%, respectively. There is no change in the exposed stiffener area per square foot of superficial bulkhead area. The number of parts is reduced 55% and 49.5%, respectively.

From No. 4, of conventional welded construction, to No. 6, of the proposed buckle plate construction, each for transverse bulkheads in connection with two longitudinal bulkheads and for ships 37 ft. 0 in. and 38 ft. 0 in. deep, respectively, a nearly direct comparison is obtained.

There is a marked change in items other than weight. Weight per square foot is reduced about 8.5%, notwithstanding a greater minimum thickness of plating in the buckle plate bulkhead. Including the sloping sides of the buckles, stiffener area per square foot of superficial area of bulkhead is reduced 30%, total number of parts is reduced 35%, number of parts to be assembled by the shipyard is reduced 62%, total length of welding required is reduced 42% and length of welding to be done by the shipyard is reduced 49%. These percentages refer to a basis of one sq. ft.

The tops and bottoms of the buckle plates forming the trough-like channels slope 20 degrees, leaving no place for oil to collect. Cleaning is naturally greatly facilitated as only the face plates on the webs and the flanges on the web brackets have blind surfaces to the front. In the buckle plate bulkhead No. 6, the top plates, 6 feet deep, are 17% thicker than the top plates of bulkhead No. 4 and therefore will last longer before replacement is required.

Emergency repairs when necessary can be made by the usual riveted construction or if this is not desired,

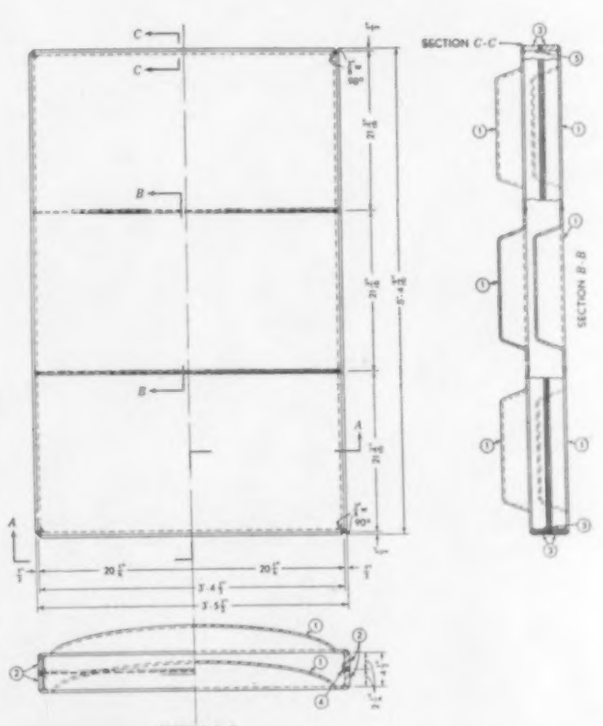


Fig. 6—Diagram Showing Exact Dimensions of Model Tank Used in Test of Proposed Welded Steel Bulkhead System. Plate Thickness throughout the Model Was 1/16"

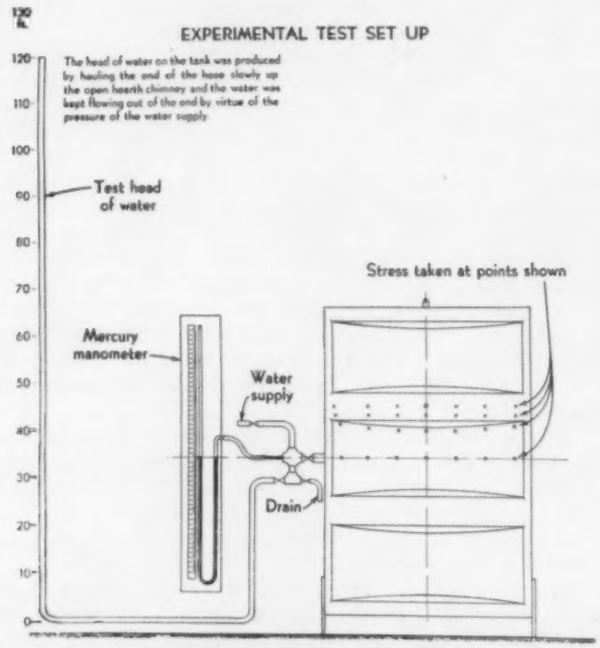
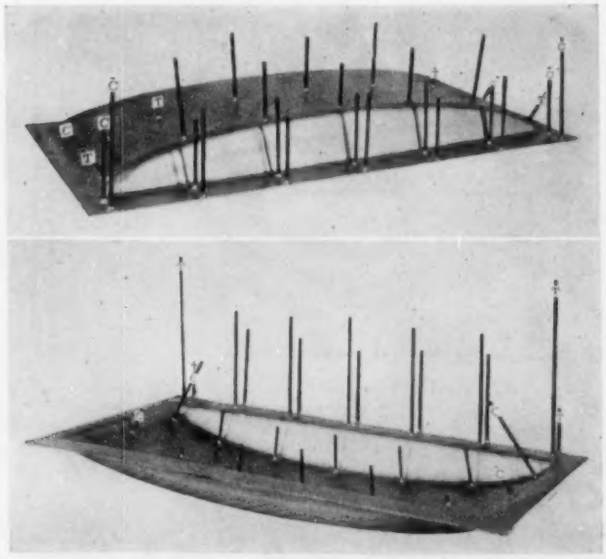

EXPERIMENTAL TEST SET UP
The head of water on the tank was produced by hauling the end of the hose slowly up the open hearth chimney and the water was kept flowing out of the end by virtue of the pressure of the water supply.
Test head of water
Stress taken at points shown
Mercury manometer
Water supply
Drain

Fig. 7—Schematic Drawing Showing the Experimental Test Set-Up for the Model Tank Used in the Test of the Proposed Bulkhead System

the buckle plate can be fabricated in the recommended form by welding several plates together.

At about the level of the top of adjacent floors or transverses, an extra wide flat part will be required to permit the attachment of flanges of oil pipes. It is estimated that about six or eight dies will completely cover the requirements of the naval architect, providing a discreet selection of dimensions is exercised. Away from the middle body, there will occur the necessity for using more horizontal stiffeners of the conventional type at and above the bilge and outboard of the outer web.

To give some idea of the utilization of these plates in a proposed all-welded tanker, it is to be noted that about a thousand and fifty separate buckle plates of possibly two or three sizes will be required. The boat under discussion is 495 feet long, with a tank capacity of about 5,530,000 gallons.



Figs. 8 and 9—Model Buckle Plates, with Rods Affixed, the Length of Which Indicates the Intensity of the Stress at That Particular Point

In order to test the proposed new bulkhead system, a flat tank was constructed, with sides composed of three pressed buckle plates, to a model scale of $^3/_8$ths, and tested under hydrostatic pressure. Figure 6 shows the exact dimensions of the model tank, in which the thickness of the buckle plates used was $^3/_{16}$ in. Three buckles were used in order that the outside buckles would simulate the type of connection that the center buckle would have. All the stress measurements were taken on the center buckle only. In the experimental tank, the bulges are so placed that the same pressure is exerted on the concave side in one instance and on the convex side in the other.

In making model tests, two principles must be observed. First, the model must be exactly scaled down in all dimensions according to the model scale employed. Second, the relations of stress, deflection and load must be examined in order to interpret the data properly. The following example will be sufficient to make clear the stress-pressure relationship for the case under discussion.

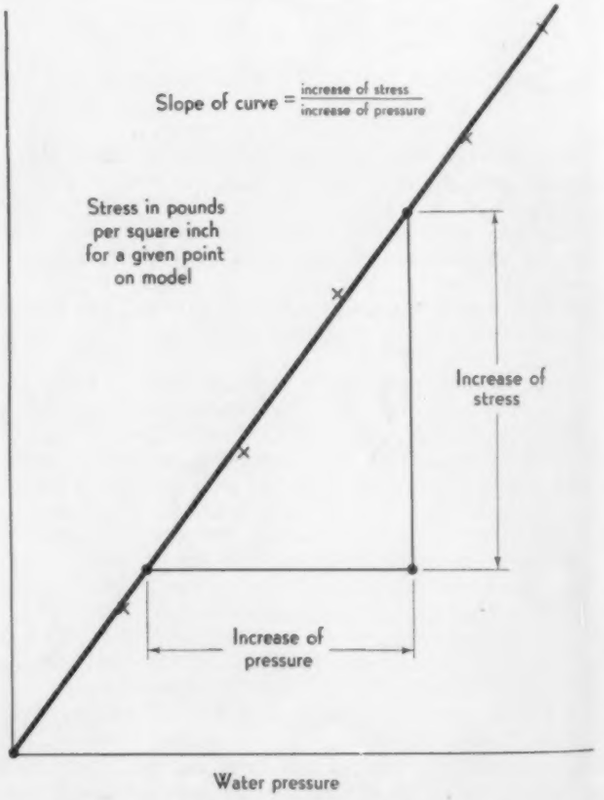

Slope of curve = increase of stress / increase of pressure
Stress in pounds per square inch for a given point on model
Increase of stress
Increase of pressure
Water pressure

Fig. 10—Chart Showing Curve Typical of Those Obtained from Stress Measurements Taken at Various Heads of Water

Assuming that the full size pressure vessel for which a model test is to be made is an 8-in. pipe with a 1-in. wall thickness, a $^3/_8$th size prototype would be 3 in. in diameter with a $^3/_8$-in. wall section. All dimensions have thus been scaled down by the model scale. Now calculate the hoop stress in each pipe as a function of the pressure by the usual formula, stress equals diameter times pressure over twice the wall thickness.

From this example, it will be seen that for the case of a pressure vessel, the same stress exists in both the full size vessel and its smaller prototype for the same pressure. Whatever phenomena occurred during the destruction test would occur in the full size model at the same head of water.

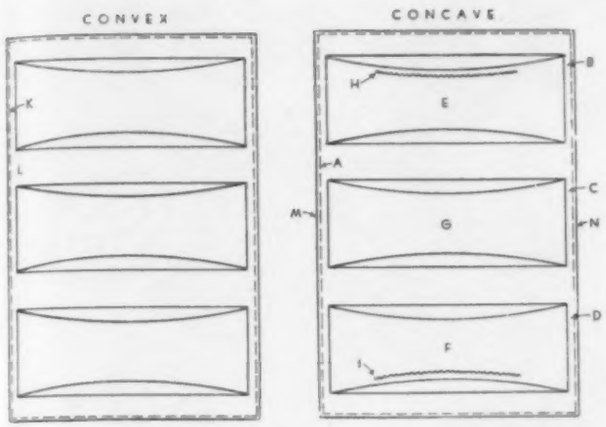


Fig. 11

Figure 7 shows schematically the experimental test set-up. Stress measurements were taken at the points shown and the results of these preliminary stress measurements have been shown in Figs. 8 and 9.

Stress measurements were taken by means of Huggenberger Extensometers at various heads of water. Enough points were taken at each position so that the linear variation of stress with head was established. Fig. 10 is typical of the type of curves that were taken at each point. The slope of the line determined from the experimental data measures the rate of increase of stress at a point for a unit increase of water pressure. It is these values that have been used in determining the length of the rods which project from various points of the model buckle plates shown in Figs. 8 and 9. The longest rod, therefore, shows the point at which the stress is increasing the fastest. It is, therefore, an indication of the point at which failure may be expected to occur first. The shortest rods in Figs. 8 and 9 show the places where the buckle plate is least loaded. In each picture, the rods project from the side of the buckle plate opposite to that to which the pressure was applied. It is, therefore, only necessary to divide the yield point of the material by the stress per square inch per pound of water pressure to determine the pressure of water at which yielding of the model would be first expected to occur.

A test report of the material used in the construction of the flat tank model shows a yield point of around 40,000 lb. per sq. in., and the length of the longest rod represents a rate of stress increase of 600 lb. per sq. in. per foot head. It was, therefore, expected that yielding would first occur at a head of water of about 66 feet.

To facilitate the location of this point of first yielding,

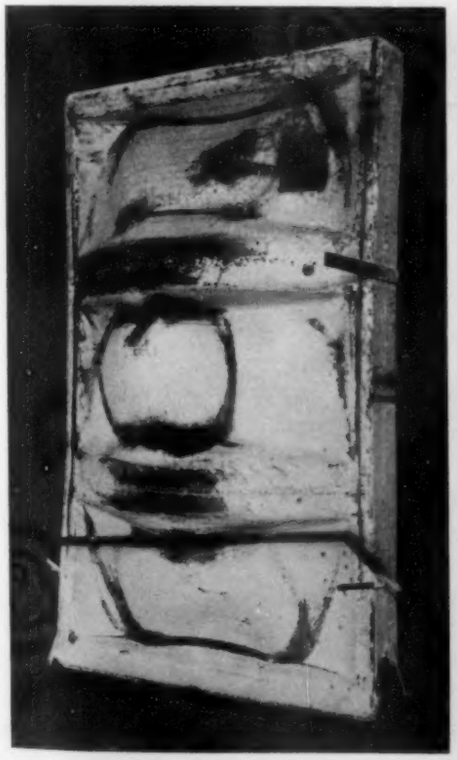
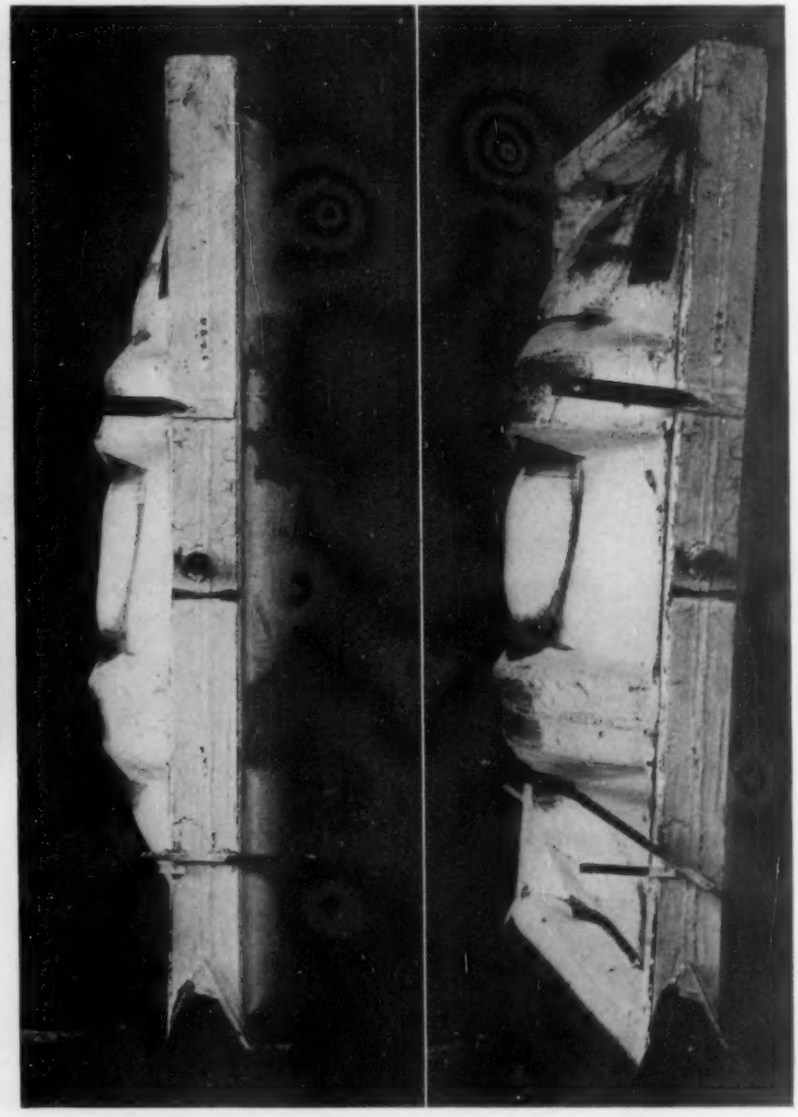


Fig. 12—Photograph Showing Deformation in Model Bulkhead Tank after It Had Been Subjected to Test at 131 Ft. Head of Water



Figs. 13 and 14 (Right)—Two Other Photographic Views of the Model Bulkhead Tank after the Test at 131 Ft. Head of Water

the model was sandblasted and then coated with a thin coat of whitewash which was allowed to dry thoroughly. The whitewash, being a brittle substance, would flake off first at the point where yielding first began.

Description of Destruction Test

Following is a description of the destruction test. The letter symbols refer to the respective locations indicated on the diagrams of the concave and convex sides of the model tank as shown in Fig. 11.

Head in Feet of Water	
10	Whitewash coating showed no sign of flaking.
20	Whitewash coating showed no sign of flaking.
30	Whitewash coating showed no sign of flaking.
40	Whitewash coating showed no sign of flaking.
48	TEST HEAD REQUIRED BY AMERICAN BUREAU OF SHIPPING. Whitewash coating showed no sign of flaking.
60	FIRST SIGN OF FLAKING OF WHITEWASH COATING AT POINT "A" where buckle plate was welded to the inside of the frame.
70	No further flaking observed.
80	FLAKING BEGAN AT POINTS *"B," "C"* AND *"D."* Flaking at point *"A"* increased downward.
90	Flaking continued at points *"A," "B," "C"* and *"D."*
100	Flaking continued at same four points.
110	FIRST SIGN OF FLAKING ON CONVEX SIDE AT POINT *"K."* Flaking on concave side continued at points *"A," "B," "C"* and *"D."*
115	BUCKLE PLATE *"E"* BEGAN TO BULGE, WITH FLAKING BEGINNING AT POINT *"H."* PLATE *"F"* STARTED TO BULGE SOON AFTER PLATE *"E,"* WITH FLAKING BEGINNING AT POINT *"I."*
120	PLATE *"G"* BEGAN TO BULGE. Flaking and bulging continued on plates *"E"* and *"F."*
125	ENTIRE CONCAVE SIDE SLOWLY ATTEMPTED TO TAKE THE FORM OF ONE LARGE CONVEX BULGE, POINT *"G"* HAVING BULGED OUT APPROXIMATELY 10 IN. FROM ITS ORIGINAL LOCATION. SIMULTANEOUSLY, SIDES *"M"* AND *"N"* BOWED IN, CAUSING THE CHANNELS ON THE CONVEX SIDE OF THE BULKHEAD TO BULGE OUT AT THE ENDS.
131	This head of water was the highest obtainable with the available facilities, due to the fact that the open hearth chimney, up which the hose was carried, was only 131 feet high. It was held for about one-half hour, with the test bulkhead tank finally assuming the shape shown in Figs. 12, 13 and 14. WITH ALL OF THIS DISTORTION, THERE WAS NO SIGN OF LEAKING IN EITHER THE PLATES OR THE WELDS.

The piece of plate, about 6 in. square, cut from the test tank, was removed to prove the thickness of the metal in the buckle plates was only $^3/_{16}$ in.

Controlling Heat Effects

By OWEN C. JONES†

Alignment Maintained without Preheating in Bronze-Welding Large Gears

GENERALLY speaking it is recommended strongly that heavy castings be totally preheated before welding, even, in certain cases, before bronze-welding. Preheating is especially effective in overcoming alignment difficulties when bronze-welding where the casting's section is eccentric or of varying cross section. This is particularly true in the case of wheels or gears, in which a balanced stress condition exists before the part breaks. The balance is disturbed when a fracture occurs. The application of welding heat without considering this section would almost certainly cause misalignment.

It is for this reason that almost without exception such parts should be thoroughly and carefully totally preheated to at least a black heat.

Where expert supervision is available, the bronze-welding of even large and complicated castings is sometimes done with relatively little preheating. The determining factors are: the type of casting, the nature and location of the fracture and the experience and specialized knowledge of the man who directs the work. An understanding of the action of metal shapes under stress of heat can be obtained only through practical experience. There are certain individuals who, by reason of their highly specialized training and experience, can be considered competent to judge when it might be possible to limit the preheating and how to proceed with the control of the heat effects, if total preheating is omitted. Oxyacetylene service operators and engineers, because of their wide experience, are competent to give such an opinion and advice. There are also a few operators throughout the country who, because of long and varied experience in repairing complicated cast shapes, can be considered competent to decide about this. In general, therefore, total preheating is recommended unless the advice of an oxyacetylene service operator is available.

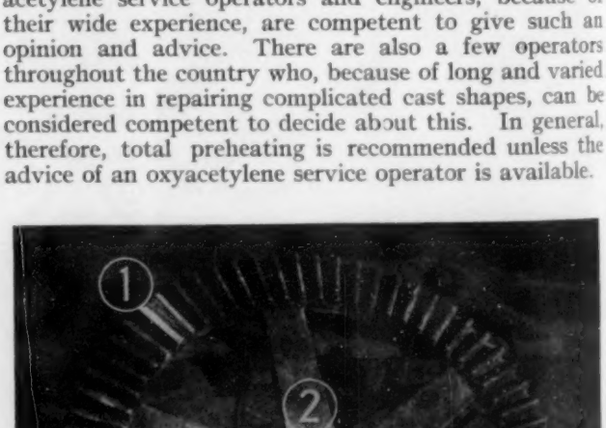


Fig. 1—Cast-Iron Bevel Gear Successfully Bronze-Welded without Preheating

† Technical Publicity Department, The Linde Air Products Company.

Fig. 2—Careful Procedure Was Necessary Because of the Variations in Thickness in This Casting

When such special cases are encountered, however, they are well worth studying, because (1) it is always instructive to follow the reasoning of an expert in any line of work, and (2) study of such jobs will emphasize the necessity of seeking expert advice.

Two recent jobs involved the bronze-welding of heavy gears. In each case, several fractures in various parts of each gear were bronze-welded without preheating. In each case the work was completed with the gears in perfect alignment. The secret seems to lie primarily in the well-studied plan of attack suggested by the service operator who was called in on the work to give his advice.

In the first case a cast-iron bevel gear, 35 in. in diameter, was welded with all-purpose bronze-welding rod. This gear was used by a smelting and refining company for driving roaster plows. There were four fractures, one each on opposite sides of the rim and two in the same line with these first on opposite sides of the hub.

A thorough study of the nature and location of the fractures convinced the service operator that the work could be done successfully without total preheating by taking advantage of the lower heat of application of bronze-welding.

For this work the fractures were chipped out to form a vee with a 90-deg. included angle. The chipped surfaces were ground and thoroughly cleaned. Following this, the welding procedure was as follows:

The gear was aligned and tack-welded at all four breaks. Welding was then started on one hub fracture, at point 2 (Fig. 1). As soon as the first part of this weld at point 2 had cooled sufficiently to have strength, the tack-weld at point 1 on the rim was melted out to permit the gear rim to expand. Then point 3 on the hub was welded, at the same time melting out the rim tack-weld at point 4.

After the weld at point 3 was completed, it was permitted to cool until the rim closed at point 4. This crack was allowed to close to within $^1/_{16}$ in., and then the crack at point 4 was bronze-welded.

The operator then applied the flame to the completed welds at points 2 and 3. Two birds were killed with one stone in this work inasmuch as the smoothing up of the weld was carried out while the heat was used to cause the crack at point 1 to expand about $^1/_{16}$ in. The final weld was then made at point 1. The entire welding operation required less than 2 hr.

When welding was completed, the rim of the gear was covered thoroughly to permit it to cool down slowly and evenly, but the hub was left exposed so that it would cool faster.

The job turned out in fine shape and the gear has been in operation under a heavy load for some time.

The second gear had seven breaks, five in the rim and two close to the hub. Again a close study of the locations of the cracks showed the oxyacetylene service operator that the work could be done satisfactorily by bronze-welding with only local preheating with the blowpipe. The accompanying illustration which shows this gear is also marked, so that the procedure for welding can be easily followed. In this case two operators welded simultaneously. The fractures at points 1 and 2 were completed together. Likewise the fractures at points 3 and 4, and next at points 5 and 6 were welded in pairs in the order mentioned. Inasmuch as this gear had a split hub, it was unnecessary to preheat the hub while the weld was made in the fracture at point 7.

This particular job required 85 lb. of bronze-welding rod; it was completed in 38 hr.

Undoubtedly a similar procedure could be followed in the case of a gear having a solid hub, with this exception: Before welding the final break at point 7, the flame should be applied to the hub to heat it sufficiently so that the break at point 7 will spread and keep the spacing while the welding is going on. Then when the cooling is carried out, the hub section should be permitted to cool faster than the rim.

It cannot be stressed too strongly that expert advice be obtained before attempting such work. Ordinarily it is recommended that large or complicated castings be preheated to a black heat. Success would then be assured. The type of job described here is but one of the exceptions which can be considered to prove the rule.

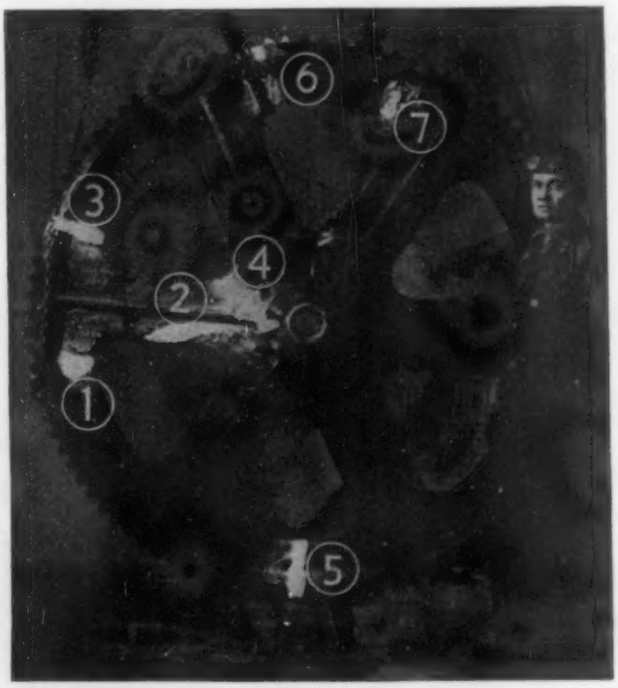
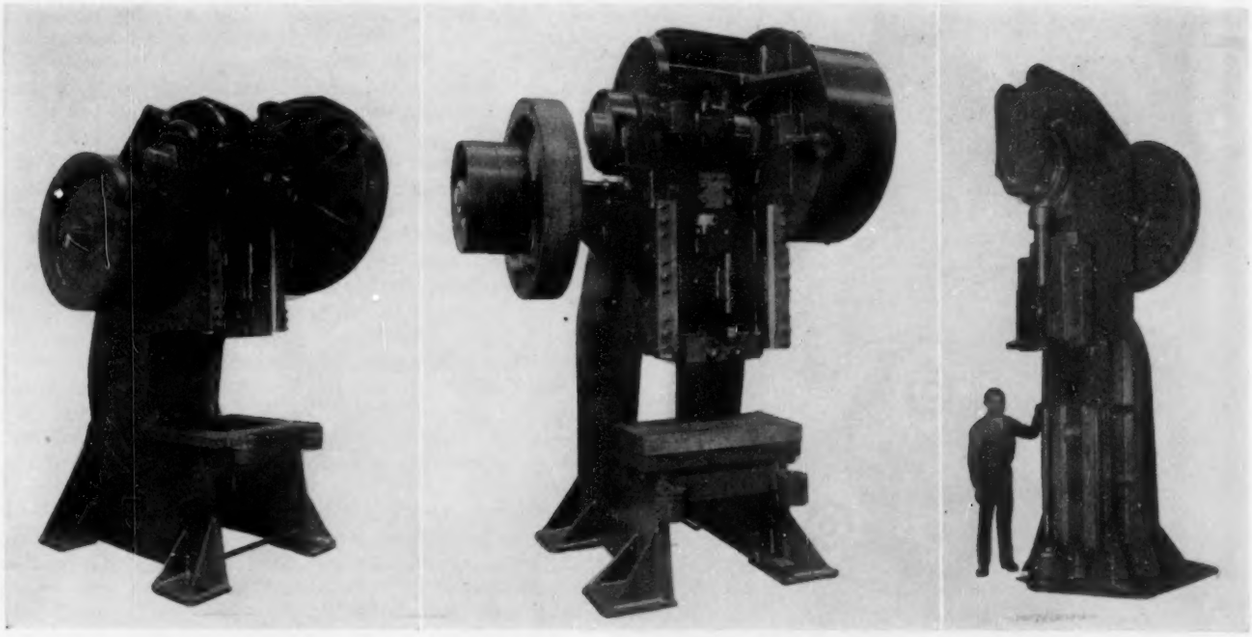


Fig. 3—Large Split Hub Gear with Seven Fractures, Bronze-Welded Successfully without Preheating



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Economical Welding Procedure in the Shop*

By HAROLD VERSON†

ALTHOUGH a comparatively new industry, arc welding has become a necessity in many fields of production. There are very few industries, if any, that have not felt the needs or benefits of this type of construction and it is because of the very great possibilities offered by the arc welding process that we must temper our rapid progress with some good sound reasoning.

We all know that everything cannot be welded economically; that some parts are not only less expensive to cast, but because of shape or application a casting may suit the purpose better. A great many present designs embody cast members welded to rolled sections or plates. The designer must determine very early in the design of a welded unit the most economical procedure. If this is not done, the cost sheet will tell it at a glance. However, in most cases the cost of a welded product is governed largely by the procedure adopted in the shop.

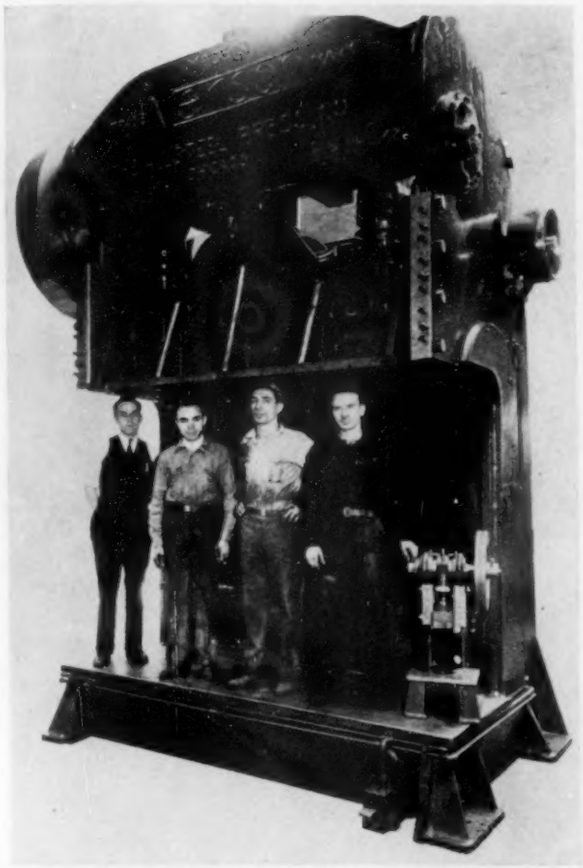
The punch press industry represents that type of construction and application that is ideally suited for manufacture by arc welding. The possibilities and benefits are equally as great to the user as to the manufacturer. The former derives the benefits of low cost, application of the finished press to his own product, and the all-important argument of quick delivery, while the latter enjoys first, freedom of design and second, the concentration of raw materials. The latter cannot be over-emphasized for instead of depending on pattern-makers, foundries, trucks and many other sources of supply and delivery, the firm specializing in arc-welded machines need only look to the steel mill for control of its promised delivery.

Some persons specialize in furnishing only the welded units to other firms. The outset of such units is confined strictly to given specifications and a good knowledge of gas cutting and electric welding. A second class of persons comprises those in which one firm designs, welds and finishes the complete product. This type of output in which the designing, welding and finishing is controlled at one source is the more important and far more complicated of the two. The finished product must be checked at four vital points for costs. The first in the design, second, cutting, third, welding and the fourth in the time of machining.

It has been my experience that in many instances a welded unit has met with disaster, not in the welding and cutting room, but on the machine tool where it had been sent to be finished. The designer must not only have a full practical knowledge of cutting and welding, but must also know machining costs, especially where

* Presented at May 24th Meeting, Chicago Section, A. W. S.

† Chief Engineer, The Allsteel Press Company.



Extremes of Proportions That Are Easily Possible through Arc-Welded Construction

the machining possibilities are limited. A welding engineer will do well to regularly follow certain jobs through the shop. This not only gives him a clear and basic conception of the problems involved there, but also gives him valuable information in regard to the cost of his product. He will most certainly determine stages where savings may be affected without any radical change in design.

In this discussion we must assume that the design of the product is correct, that the weight is reduced to a minimum and that the entire unit has met with favorable approval by the trade. It is also well to know that although the type of product I am referring to is of standard design and principle, the specifications, application and procedure vary almost daily, so that constant design and close inspection is absolutely necessary for reasonably low cost.

Economical welding begins in the engineering department. The shop must first of all receive an assembled print of the frame on which he has not only a sufficient number of views, but also a designation of every piece of steel comprising the entire unit. This print is necessary for the welder and machine tool operator. The designer should make it easy for the welder to look at the print and be able to go to the cutting room and pick out every piece designated.

It is not essential that the man operating the cutting torch have this print. What he wants is a series of small blue-prints, or in cases of varied designs, cutting sketches which can be made in carbon duplicate. These sketches should give him the correct shapes and thicknesses of every piece of steel in the frame, and his job is to cut those plates within the limits shown, mark the job numbers on each piece and put them all in one place where they can be readily picked up by the welder. It is well to educate the cutter in close limit cutting, not only because of appearance of the finished structure, but because a structure can only be lined up as close as it has been cut. Very often a few minutes' care on the torch will save two men's time in the welding room, and a possible recut.

The cutting sketches are a great advantage for possible savings in costs. It is possible to utilize them for many practical purposes. They may show beveled edges that may be necessary for welding, or they may show a few preliminary welds that may be made more economically and better before the entire structure has been tacked together. It is sometimes necessary to show certain holes on cutting drawings that would be impossible to drill in assembly. Such holes would no doubt be cored in a cast frame, and the reason for showing them on the cutting sketch is for emphasis, and to make certain that they are not left out. If only the assembled blue-print shows those holes, it will be assumed that they are to be drilled later and would entail an unnecessary expense.

If the cutting has been done correctly, then the cost of the finished unit is dependent on two governing factors: one is the procedure in the welding room and the other is the demand of the machine tool limits on that procedure. Economical finishing is only possible by welding to close limits and one way to insure close tolerance welding is by putting the right man in charge of the welding room. His duties are to line up every unit piece by piece so that the welder can keep tacking them together. The ideal man for this capacity is one who has recently been employed in finishing these same structures on some machine tool. A planer hand or milling machine operator is preferable.

It may seem to some that an extra man in the welding room is superfluous and an unnecessary expense, and that the welder should be able to line up and tack his own units, but this idea will soon be expelled by a close inspection of what this man does. To begin with, he is able to grasp the entire structure by a glance at the blueprint. He knows that a few minutes' careful lineup will save him one or two extra cuts on the machine tool. It may be that a rough preliminary cut on one piece before welding will be the natural means of lining up the entire unit. This one surface can probably be utilized in squaring up the unit on the planer or milling machine table later. Frequently, in haste, a draftsman will fail to show proper clearance for the tool on a finished surface. The right man will correct it by having some small planer or shaper provide this clearance with a few preliminary cuts.

The value of preliminary planing of later to be finished surfaces is very important, because a rough cut on the individual piece done on a small planer will surely save hours on a more expensive machine. The very least that this preliminary planing will do is save at least one roughing cut later on, and when the structure assumed ten and fifteen foot proportions such cuts are costly.

A machine tool operator fully appreciates the value of welding to close tolerances, and such a man can often, with the consent of the engineer, of course, insert a few light ribs or triangles in the right place, so that the structure will be less inclined to pull in welding. It is often advisable, where the structure resembles a box section, or where ribs control the shape of the unit, to finish these ribs on the ends so that they will be instrumental in making a more homogeneously welded job.

It has been often said, and wisely too, that the best welded job is that one on which the least welding has been done and this is easily possible by correct layouts and careful supervision.

A Study of Porosity in Metallic Arc Welding under Specific Conditions*

By J. S. JOHNSON†

Introduction

IN THE making of automatically welded butt joints with the metallic arc, it is a common practice to back up the seam being welded with a copper bar, in the manner shown in Fig. 1. This bar serves to support the plates and to chill and solidify any molten metal that comes to the back of the seam.

In the welding of plates up to $^3/_8$ of an inch or so in thickness, it is possible, under ordinary conditions of operation, to penetrate the full depth of the plates, and to seal and fill the entire depth of the seam in one pass. If this is done, the molten metal is present across the entire section at one time, and is in contact with the copper backing bar.

The other alternative is to make two or more passes, using lower currents, and depositing in each pass a thinner layer of metal. In this case, at least one pass is generally made from the reverse side of the seam to care for that part of the weld.

The particular difficulty under consideration arises when the full depth of a seam is welded in one pass, and molten metal is present on the side of the plates opposite to that from which they are being welded. This metal comes in contact not only with the backing bar, but with any oxide present on the back surface of the plates. Almost invariably there is an accompanying porosity, which can be definitely associated with these conditions, even though the plates, welding rod, flux, speed of travel, and current and voltage values are such that there would be no porosity if penetration of the plates were not complete. The character of the porosity can best be illustrated by a cross section through a typical hole (Fig. 2). The holes are profuse, and are generally large in size. It will be seen that this problem is distinct from those arising from the fact that satisfactory results are not obtained with certain steels, rod, etc.

* This paper is based on a thesis of the same title in partial fulfilment of the requirements for the degree of Master of Science in Mechanical Engineering at California Institute of Technology, Pasadena, California.

† Personnel Representative, Southern California Gas Co. Formerly Teaching Fellow in Engineering, Calif. Inst. of Tech.

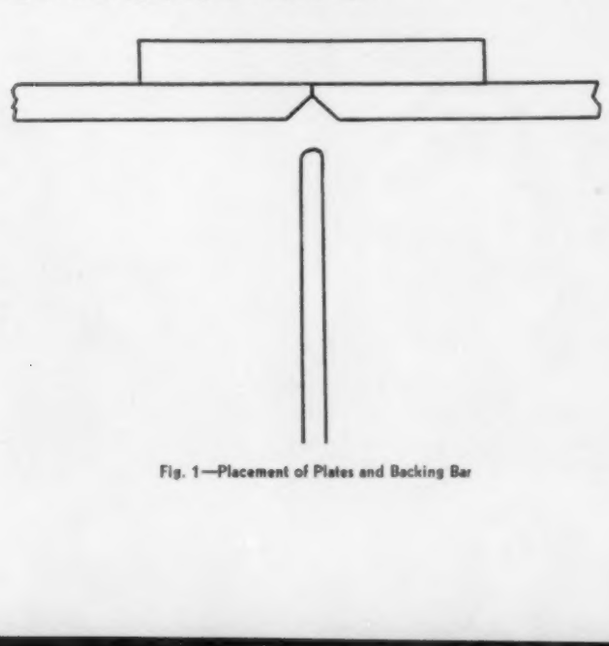


Fig. 1—Placement of Plates and Backing Bar

Literature and Current Opinion

The reason for this occurrence is undoubtedly known to many. However, before any actual work was undertaken, most of the large manufacturers of welding equipment, as well as a number of the people whose names are familiarly associated with the art, were contacted in an endeavor to see what light they might cast on the subject. In the suggestions which were offered four or five theories seemed to be commonly entertained. As for the literature on the subject, the writer was able to find very little that had any direct bearing. Most discussions which dealt with porosity were concerned with empirical means of eliminating it, rather than an endeavor to find out what really caused it. Furthermore, there was very little material pertaining to automatic welding. As a result, it was felt advisable not to try to make use of the experience of others in this work, but to proceed independently.

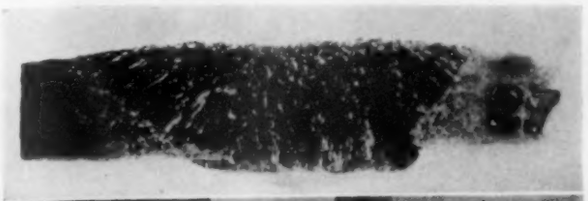
Theoretical Considerations

At first the question arose as to whether the holes were definitely filled with a gas, or whether they might be evacuated. However, an attempt to conceive of any possible means whereby the effect of atmospheric pressure could be overcome, and small evacuated pockets could be formed in the weld metal, led to the conclusion that the pockets were undoubtedly filled with a gas. Furthermore, in some of them which had worked their way to the top of the weld, evidence was found that gas was flowing out at the time at which solidification took place.

An inspection of the inner surface of the holes disclosed the fact that they were clean and bright, without the slightest sign of oxidation. Evidently, any gas which was present was not active enough to oxidize the steel. Oxygen was immediately eliminated. Carbon dioxide was very likely ruled out by the fact that its equilibrium with carbon monoxide is such that it is practically nonexistent at the temperature of molten steel, if there is any carbon present. The presence of large quantities of nitrogen within the weld seemed highly improbable, although this was a possibility to be considered as a last resort. The evidence indicated that carbon monoxide was the gas which was most likely to be present under the circumstances. There are three conceivable sources of large quantities of carbon monoxide.

There are generally oxides present at the back of the plates being welded, both on the bottom of the plates

Fig. 2—Cross Section through Typical Hole



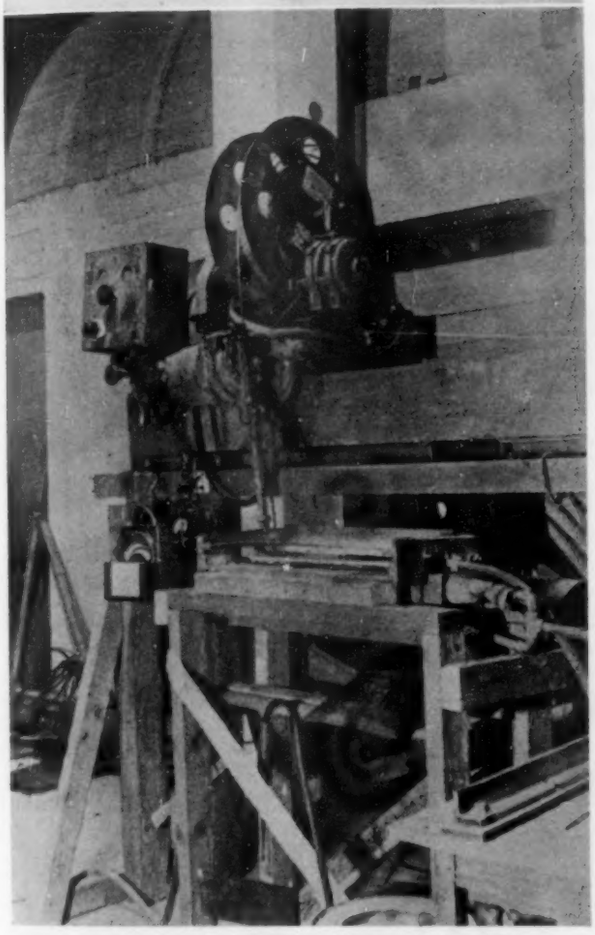


Fig. 3—Welding Apparatus

themselves and on the top of the backing bar. If these oxides are reduced during the welding operation, they will give up oxygen, which, in turn, can combine with the carbon in the molten steel, forming carbon monoxide.

Whenever there is any rust (Fe_2O_3) present, the following considerations are pertinent: Braithwaite[1] has noticed that at a dull red heat the following reaction takes place: $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$. Thence, $CO_2 + C \rightarrow 2CO$. The net result is that the oxide has been partially reduced and the volume of CO has been increased. The melting point of steel is well above a dull red heat, and it is to be expected that this reaction, or other reactions in the same direction, will take place readily at the temperatures existing.

In speaking of the casting of steel ingots, Williams and Homerberg make the following statement:[2] "The use of rusty molds may produce a regular honeycomb effect in an ingot or casting due to the formation of CO and CO_2 as the result of the reaction of the carbon in the steel with the iron oxide constituting the rust...."

[1] J. W. Mellor, "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," Vol. XIII, p. 812.
[2] "Principles of Metallography," p. 195.

Likewise, there is generally cupric oxide or cuprous oxide present at the surface of the backing bar. Mellor[3] makes the following observation: Cupric oxide "is partially decomposed when the vapor pressure of the oxide attains one-fifth that of the atmosphere: this occurs at a red heat; the reaction is $4CuO \rightarrow 2Cu_2O + O_2$, and the porous mass reoxidizes when cooled in air." This reaction, if followed by a combination of the oxygen with the carbon in the steel, might also be one that could cause trouble.

It should also be remembered that all of the steel that is deposited in the weld has passed across the arc, which is at a temperature of several thousand degrees. In the molten state, steel can absorb a considerable quantity of carbon monoxide. This is probably present in the arc, as shown by the fact that a great deal of carbon is usually lost from the steel during welding. It is not unreasonable to suppose, then, that a considerable quantity of carbon monoxide might become dissolved in the steel and carried to all parts of the weld. A rejection of this gas during solidification might account for a lot of porosity. Also, most steel used in welding is "rimming" steel; that is, steel which is incompletely deoxidized. Any oxygen or oxide remaining in the steel could also be responsible for considerable quantities of carbon monoxide.

If the gas were dissolved in the steel, or were coming from the top of the weld in any form, the question arises as to why it should cause porosity when there is penetration through the plates and not otherwise. A possible explanation is that the rate of chilling which is concurrent with penetration and with contact with the backing bar is sufficiently rapid to cause gases to be trapped which would otherwise escape. When a pool of molten metal is in contact only with plates, the adjacent portions of which have been heated almost to the melting temperature, its cooling will be less rapid than it would be if contact with a cold surface were established.

"Magnetic blow" is often thought to be a cause of porosity in welds. The author does not believe, however, that it is a factor which need be considered in the case at hand. In the first place, magnetic blow can, by its very nature, consist of nothing more than a pull of the arc in the direction of the strongest magnetic field. This results in an instability of the arc, but not a whirling motion of the pool of metal, as is sometimes believed. On flat plates the blow is generally toward the center of the seam, and is negligible over the central two-thirds portion for the size of plates used in this experiment.

Experimental Work

The welding apparatus used was in general of a standard type. An automatic welding head was mounted on a carriage which moved at a controlled speed (Fig. 3). The current was supplied by a 600-ampere arc welding generator. A plate holder containing a section of hose which could be inflated by means of compressed air was used. This pushed the backing bar up and held it firmly against the test plates, which were restrained from the top. The plates and backing bar were thus held in proper juxtaposition. X-ray work was done with a small tungsten tube.

The plates used throughout this test were of low-carbon steel. They were all cut from the same piece of stock, and, consequently, the analysis of the steel did not constitute a variable. The thickness of the plates was $^1/_4$ of an inch, and the other dimensions were roughly 8″ x 18″. The specimens were given a 45° vee on one edge to within $^3/_{32}$ of an inch from the bottom.

[3] "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," Vol. III, p. 133.

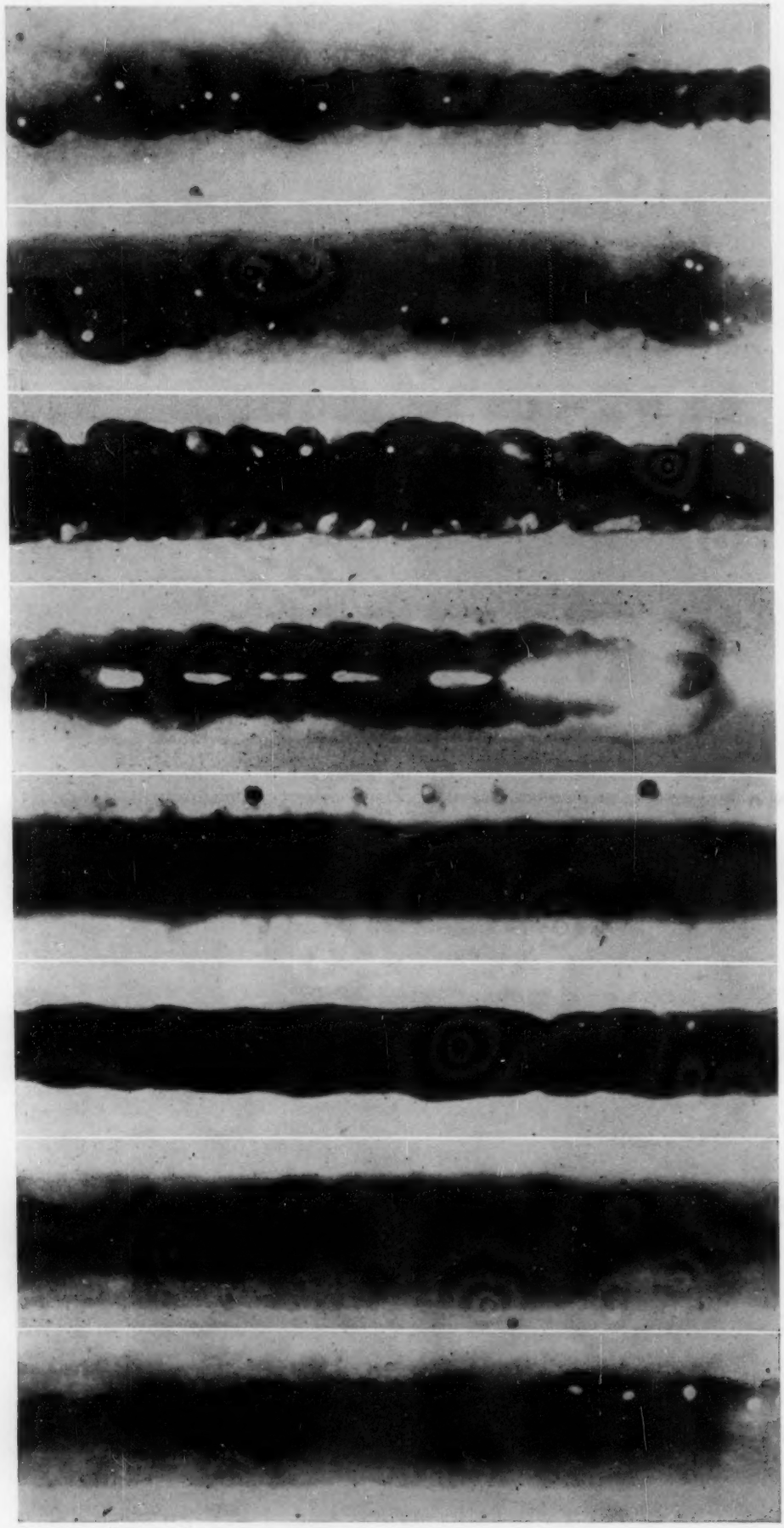


Fig. 4—Copper Bar 335° F.

Fig. 5—Copper Bar 1020° F.

Fig. 6—Nevastain Backing Bar

Fig. 7—Refractory Brick Backing

Fig. 8—Bead Passed along Surface of Single Plate Central Portion Cooled by Stream of Water

Fig. 9—Nevastain Backing Bar, Fe_2O_3 Removed from Back of Plate

Fig. 10—Copper Backing Bar, Fe_2O_3 Removed from Back of Plate

Fig. 11—Copper Backing Bar, Fe_2O_3 Removed from Back of Plate for Two-Thirds of Length of Seam

A $^3/_{16}$" bare steel wire electrode was used. Fluxing was accomplished by means of a powder which was placed upon the seam being welded to a depth of about one-half inch. This was a mineral flux, whose principal function it was to coat the droplets of metal as they crossed the arc, and to form a slag over the surface of the molten pool.

There were two different metals used for backing bars —electrolytic copper and Nevastain A. Nevastain A is a high chromium steel of the following composition: C, under 0.10; Mn, under 0.50; Si, over 0.30; Cr, 16–18; P and S under 0.025. It has a very low thermal conductivity. Both bars were approximately four inches wide, twenty inches long, and five-sixteenths of an inch thick. A cut one inch wide was made along their flat top surface. The purpose of this was to facilitate complete penetration. It was approximately 0.030 inch in depth. Refractory brick was also used for a backing.

The metal bars were designed so that they could be screwed against a steel plate, which was milled out on one side and provided with pipes, thus allowing a circulation of water at the back of the bars. They were also provided with thermocouples, which were inserted from the bottom to within about one-sixteenth of an inch of the top surface. It was thus possible to determine the temperature at the thermocouple tip with a reasonable degree of accuracy.

In making a run, a pair of plates was carefully tack-welded at the ends, so that they fitted tight together. After they were placed in the holder, the seam was covered with flux. Care was taken to see that no flux got to the back of the seam. Voltage and current readings were taken during the run, and in cases where temperature was recorded it was taken as the highest value reached. This differed from the actual temperature of the surface of the backing bar, but served for purposes of comparison.

It was decided first to investigate the effect of the rapid chilling of the molten metal when it came in contact with the backing bar. The procedure was to use the copper bar at different temperatures, to use the Nevastain bar, which had a much lower coefficient of thermal conductivity, and also to use the refractory brick as a backing. When using the copper, it was necessary only to make runs in rapid succession to heat it.

It is not convenient to show the radiographs of all the runs that were made, but those that are shown are typical. Figure 4 shows the result that was obtained when the copper bar reached a temperature of only 385° F. at the tip of the thermocouple. The heavy black strip along the center represents the bead that flowed out in back between the plates and the backing bar. The wider strip of medium intensity is the shadow of the bead on the top of the weld. The gas pockets are clearly visible as white spots in the weld.

When the weld shown in Fig. 5 was made, a temperature of 1020° F. was recorded. While more metal flowed out in back, supposedly because of the slower rate of cooling, the porosity is, if anything, worse. Several welds made at intermediate temperatures show little difference. Figure 6 is representative of the results obtained with Nevastain as a backing bar. The exceptionally low thermal conductivity slowed the chilling to a point at which the groove in the backing bar was practically filled with metal, and the bead on top of the weld entirely eliminated. This served to aggravate the conditions. When a weld was made over refractory brick, (Fig. 7), it was found that the pockets of gas had time to coalesce, but not to escape, making large rifts along the seam.

From the foregoing results it seems fairly obvious that the rapid chilling of the metal is in itself not responsible for the porosity under consideration. This fact was further verified by another type of experiment.

Welds were made along the surface of a single plate. By properly controlling the current, it was possible to cause the pool of molten metal to extend almost to the bottom of the plate, but not through it. Welds entirely free from porosity were obtained, as shown in Fig. 8. By directing a stream of water against a certain portion of the bottom of the plate a chilling effect upon the pool of molten metal, which was even greater than that of the copper backing bar, could easily be secured. If it were trapping of gas, either from the plate itself or from the arc, which was responsible for the porosity, the same thing should be true when the back of the single plate was cooled with water. Although there was evidence of very rapid cooling, no trace of porosity could be found.

A series of tests was then made to determine the effect of oxides present. Welds were made with the rust very carefully removed from the back of the plates. Figure 9 shows the type of weld that was obtained using Nevastain as a backing bar. While there are one or two gas pockets to be seen, the results are very good as compared with those shown in Fig. 6. Similarly, Fig. 10 is representative of the results obtained with copper. In Fig. 11, the rust was removed from approximately two-thirds of the seam, and the backing bar was of copper. The effect of removing the rust is evident. A very good weld was also obtained with refractory brick as a backing. While there are one or two gas pockets to be found in some of these welds, they may easily be accounted for by tiny particles of oxide which were not removed.

It will be noticed that the cupric oxide which accumulated on the surface of the copper backing bar apparently had no adverse effect upon the character of the weld. However, when a little cupric oxide in the powdered form was placed upon the backing bar, porosity did result. The reason for this was probably that in the former case the metal which contracted the surface of the bar solidified before it had an adequate chance to react with the oxide. If this is true, it would seem that rapid chilling is beneficial in that it inhibits the reduction of the oxides present. The fact that sounder welds were obtained with copper than with Nevastain also points to this conclusion.

In no case was the rust removed from the top of the plate adjacent to the seam, and undoubtedly a lot of gas was formed at this point. It is not surprising, however, that porosity did not result, for there was ample chance for this gas to escape from the molten metal before solidification took place.

Conclusions

The conclusions to be drawn from this investigation are that the particular trouble under consideration is caused by the reaction between the carbon in the steel and the oxygen in the scale on the lower side of the plates. The rapid chilling caused by contact with the copper backing bar is, in itself, not detrimental. As a matter of fact, it may be beneficial, in that it inhibits the reaction with the scale on the plates and the cupric oxide on the backing bar.

The soundness of weld which could be obtained when penetration of the plates was not complete, as illustrated, for example, by Fig. 8, indicates that the steel used was of good welding quality, that the flux and welding rod were good and that the conditions of operation were

satisfactory. With some steels a good weld cannot be obtained under any conditions. This is obviously a fault of the steel, and constitutes an entirely separate problem. It is possible, however, that the trouble with many steels is that they are dirty, and contain minute particles of oxide. In this case good results could certainly not be expected in the light of the foregoing study.

Acknowledgments

The author wishes to acknowledge the unstinting cooperation of the Consolidated Steel Corp. of Los Angeles, and especially of Mr. C. P. Walker, Chief Engineer, and Mr. Wayne A. Howard, former Test Engineer of that organization, and the helpful suggestions of Dr. Donald S. Clark and Professor William Howard Clapp of the California Institute of Technology.

A New Design of Spot Welding Electrodes

By G. KOMOVSKI†

ONE of the important problems of spot welding is the electrode, able to carry the work of welding a great number of spots without deformation or other physical change.

As it is known, electrodes, usually employed in industrial practice, are chiefly made of red copper, and in recent times alloys with a higher mechanical strength were brought into use.

The Technological Research Laboratory of Civil Aviation Administration has recently undertaken a systematic study of various spot welding problems, and, notwithstanding their apparent simplicity, the work has already proved extremely important.

The copper electrode usually employed in spot welding represents a rod of red electrolytic copper, tapered at the end.

When welding, the sheets of material are placed between two such electrodes and pressed, one of them being for that purpose made movable. Two factors affect the electrode at the moment of welding: (1) the force, that presses the electrode upon the surface of material, and (2) the current, that passes in the electrodes and through the surface of their contact with the sheets of metal. The force of pressing the electrode upon the surface of material must be sufficient to make the electric resistance of contacts inferior to the total resistance of the sheets (two or more). This condition is necessary to avoid the fusion of metal under the electrode, where, for that purpose, the generated heat, and, consequently, the resistance must not be too high. The value of the required pressure depends on various working conditions, and its exact examination will be subject of further research. Approximately it is equal to 5–10 kg. per square mm. of the electrode surface, and thus the total pressure of the latter upon the surface of material can amount to several hundred atmospheres.

Hence it may be stated that the deformation of the electrode wholly depends on this pressure and may be very considerable; and if the welding apparatus is not provided with a proper cooling, the influence of high temperature increases the deformation.

The importance of physical properties of the electrode tip, effectuating the contact with the material is therefore evident. To make the contact good a plastic material is needed; copper (and silver) satisfies this condition well enough.

The form of the electrode end is usually conic; but the angle of tapering is not usually indicated, though its importance for the work is not small it must not be forgotten that the current in the electrodes can attain very high values, up to several hundred amperes, and that current density (per unit section) in cylindrical

† Technological Research Laboratory of Civil Aviation.

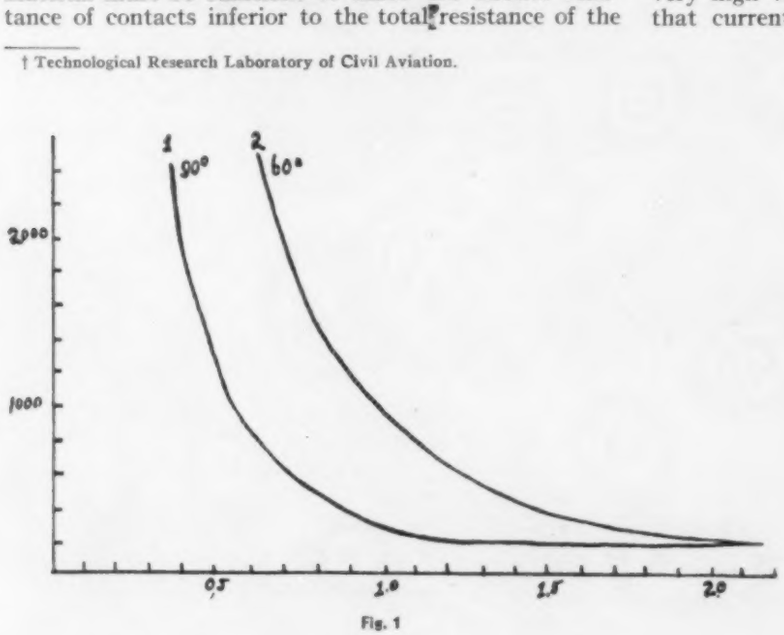


Fig. 1

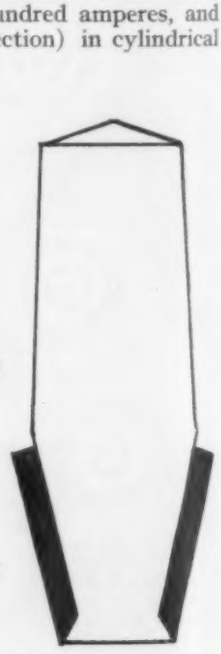


Fig. 2—A New Type of Spot Welding Electrode

electrode is constant on its whole length. The use of cylindrical electrodes for welding small spots of several mm. in diameter is obviously inconvenient, not only because of their weakness, but also because of disadvantages, presented by the equal distribution of current density through their length and, consequently, homogenous heat production.

The best form of electrode is one in which maximum heat generation takes place in the contact surface of the electrode with the sheet, and diminishes to the place where the electrode is attached. The distribution of current density in tapered electrodes is different from that in cylindrical ones, and can be expressed for each section by the following formula:

$$Q = \frac{I}{\pi \cdot h^2 \cdot tan^2 \alpha}$$

where Q is the density of the current per unit section, h the distance from the section to the vertex of the cone and α the angle between the axis and the generatrix of the cone.

Curves that represent, according to this formula, current densities in different sections of the cones with various vertex angles (without consideration of the skin effect in the case of the alternating current) look as is shown in Fig. 1. Curve 1 corresponds to the angle at the vertex 90°, curve 2 to the angle 60°. The abscissae represent the distances from the section to the vertex while the ordinates represent corresponding current densities.

It is easy to see that very high values of current density may take place in the contact surface of taper electrodes. Only their extremely short duration (parts of a second), prevents the generation of too large quantities of heat in the electrode ends; the distribution of the produced heat also follows the above curves, so that maximum heat production takes place in the contact surface of the electrodes, where, practically, in the case of some irregularly retarded interruption of the current, fusion of copper may occur. Generally, however, if the duration of welding is right, i.e., does not exceed a small part of the second, the main part of the heat in the electrodes is conveyed to them from the sheets of metal, where large amounts of heat are produced.

The consideration of the above curves shows with evidence that to obtain the best current density distribution and the best thermal efficiency, the taper angle of the electrodes must be chosen as large as possible. Considerations of purely mechanical character forbid the use of the angles above 60–90°, and in this very interval, we think, the optimum solution is to be looked for.

The deformation of the electrode end, due to the considerably lower hardness of copper, compared to steel and most of other welded materials, is usually displayed in a fungiform expansion of the tapered tip, and an alteration of its contact surface, which becomes more or less convex.

This deformation is produced in a short time, after welding 30 to 40 spots, and the electrodes need a fresh turning for further use.

Considering, first, that copper electrodes thus last a short time we have designed a new type of electrode, which has already proved good in practice.

Our principal task being to avoid the deformation of electrodes and consequent losses of time for their turning, we proposed to insert the taper end of the electrode in a casing of steel or some other hard metal, of similarly conic shape, which would prevent the deformation of copper rod at its end. The whole arrangement in longitudinal section is represented on Fig. 2.

The opening of the steel casing from the narrow end is made inversely tapered, so that, to fix the casing on the electrode, it is sufficient to hammer the projecting tip of the copper rod into this, like a rivet head. Without this sort of fastening the casing may fall off the electrode during the work, the difference between the thermal expansion coefficients of steel and copper causing a certain deformation of both electrode and casing.

The contact surface of an electrode, constructed in this way, is practically free of deformation and conserves during the whole work the same diameter of the outer opening of the protective steel casing. If the welding current is correct, the qualities of the electrode even improve with the time, which is due to an automatic smoothing of its contact surface, and the electrode welds a very large number of spots.

Observations of the electrode in work showed that a slow squeezing of the copper rod farther into the steel casing takes place in welding, so that copper is pressed out of the cone opening.

It is easy to deduce from a simple geometrical construction of the forces, acting upon the narrow edge of the steel casing, that the force required for squeezing the electrode into the casing increases proportionally to the taper angle. For preliminary research we have tried the electrodes with various taper angles, from 45 to 60°, and obtained for every one almost the same result.

It must be noted that the current passing in the steel casing may be, for the working conditions of the electrode, completely neglected, the conductivity of steel being much inferior to that of copper, and the narrow contact surface of its exterior edge still more inferior to the contact surface of the electrode itself.

The deformation of the steel edge can be minimized by using the makes of steel with the highest mechanical resistance at high temperatures (500 to 600°) which can occur at some irregular disturbances of the welding cycle.

As for the potential drop due to the presence of the steel casing, this question needs no discussion, its length being quite insignificant (8 to 10 mm.).

There cannot be any doubt that the described electrode wholly admits using any type of welding time regulators.

Summary

1. A new type of spot welding electrode is described in which, to avoid the deformation of the contact surface, the end of the electrode is enclosed in a protective steel casing.

2. The current density in various sections of the tapered electrodes is discussed and its distribution graphically represented.

A Method of Testing Welded Seams†

An Ingenius Use of a Milling Apparatus

By DR.-ING. E. h. H. SCHMUCKLER

THE large type of testing apparatus for butt and fillet-welds up to one $^3/_{16}$ in. thickness is shown by Fig. 1. By moving the miller in the longitudinal direction, this apparatus is at the same time useful for milling out bad parts of the seam. There are no notches in the resultant milling, which is to be preferred to the older method of using the cross cutting chisel; and moreover, milling is the cheaper method. The testing apparatus may be fixed to the welded piece either by two tack-welds not larger than peas, or by clamps.

A milled hole before etching is shown in Fig. 2. Such a test can be carried out in one to two minutes, showing any fault of the welded seam by visual inspection by the naked eye, or better by microscope. This result cannot be obtained in such a simple way by any other method; thus the milling test proves to be indispensable for continuously testing welded work, and of special value for the education of operators.

A milled hole after etching is shown in Fig. 3, giving necessary details of penetration and depth of fusion zone.

Recently a further use of this apparatus has been made on dynamically loaded structures by milling off the ends of fillet welds, as shown in Fig. 4.

The result of a series of tests carried out by Professor Bierett at the Institute for Testing Materials in Berlin-Dahlem showed an increase in fatigue-strength by about 60 per cent when welds had been given such a finish. The test-pieces welded in the usual manner gave maximum figures between 300,000 and 400,000 vibrations; but when prepared in the above-mentioned way, the test-pieces did not break before $2^1/_2$ million reversals had been performed. The reason for such a considerable improvement in the strength of the welded joint by such simple and economic means will be seen in Fig. 4, showing the extremities of the stress diagram being cut off, resulting in a more uniform distribution of stresses. It is obvious that this new application of the milling method will show its importance in the construction of bridges, cranes and other dynamically loaded structures, at the same time providing a thorough test for welded seams at their danger points, i.e., the end-craters.

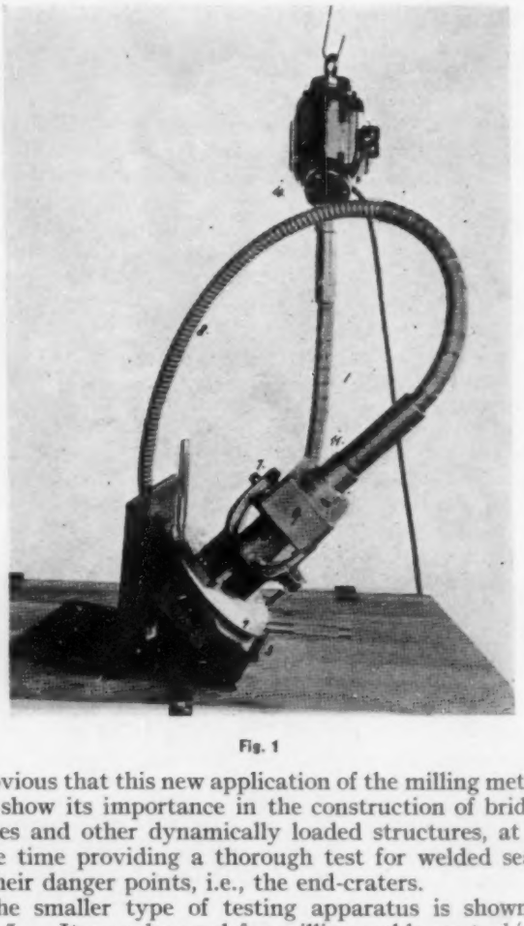


Fig. 1

The smaller type of testing apparatus is shown in Fig. 5. It may be used for milling welds up to $^1/_2$ in.

† Reprinted from *Electric Welding*, April 1935.

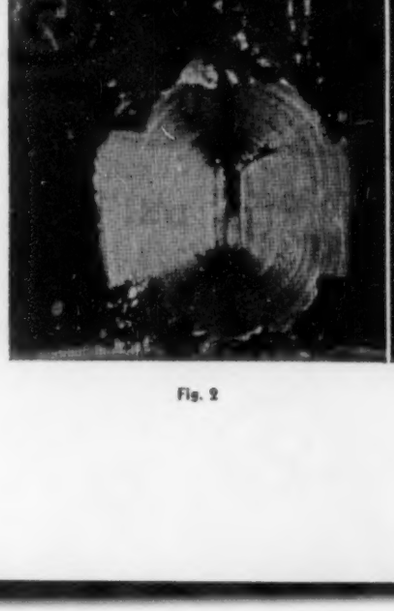


Fig. 2

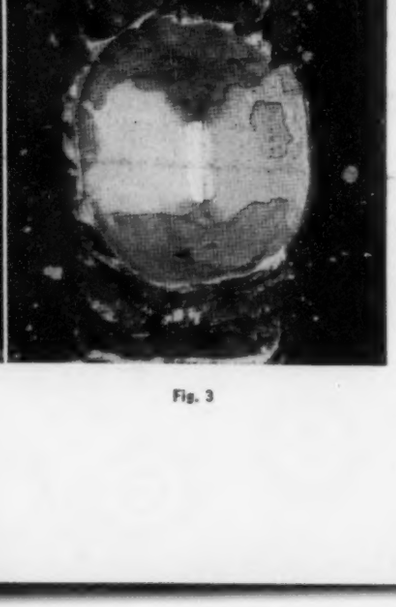


Fig. 3

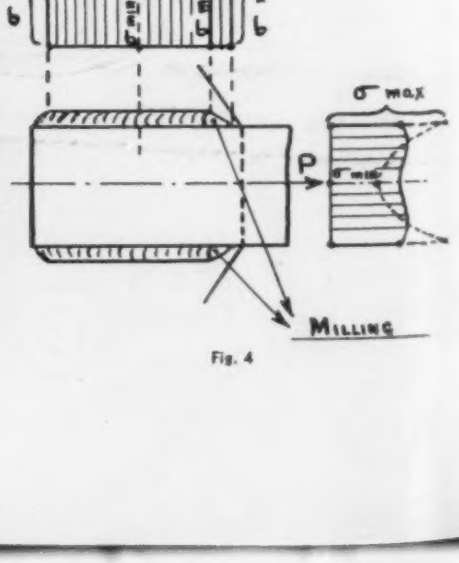


Fig. 4

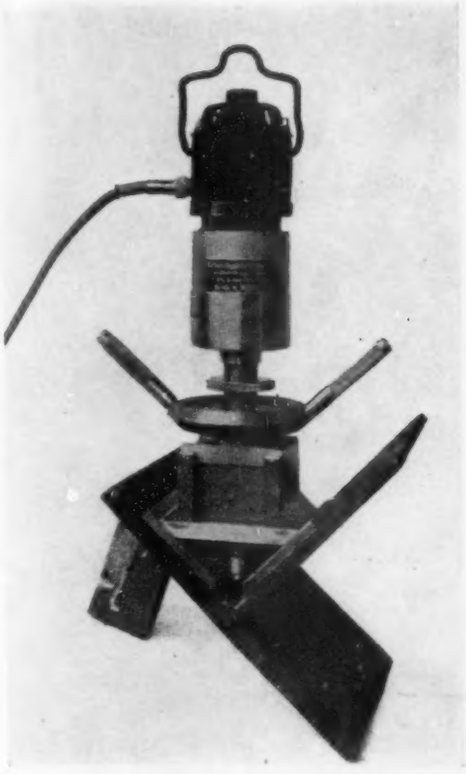


Fig. 5

thickness; and owing to its low weight, only 22 pounds, it is also suitable for testing purposes on site.

The preliminary regulations for nondestructive tests, drafted by the Committee for Welding of the Verein deutscher Ingenieure (VDI) in Berlin and published in the VDI—Zeitschrift of August 1934, contain some notes on the milling test, especially with regard to fillet welds. This method is also laid down in the Regulations of the Italian Shipping Authorities, in Switzerland and in Czechoslovakia, and for several years it has been used with success by the German State Railways and the Imperial Japanese Navy.

By making use of this test, the manufacturing industries are improving the quality of welded work, thus being enabled to guarantee its reliability. On the other hand, this method seems to be indispensable for surveyors and authorities when taking over welded constructions.

Electric Welded Construction

The article by Dipl.-Ing. F. Samuely in the June 1934 issue of *Electric Welding* deals with the methods of manufacturing welded structures and with the facilities desirable for shop work, emphasizing the advantages of the patented Schmuckler Cramp Table, but without showing the necessary illustrations. Some details are to be seen in Fig. 6, showing the table with a lattice girder on it, ready to be welded. By the use of this cramp table the assembly of such lattice work is considerably simplified, the same applies to lattice-poles, frames of doors and windows, and plate-girders. The drawbacks occurring with older methods using tie-rods, etc., can be avoided, as well as inaccuracies and internal stresses.

An example from the practice of a large German firm may give an idea of the considerable saving in cost. The order consisted of 1000 lattice-poles. As manufactured hitherto by riveting, each pole meant a net

Fig. 6

labor cost of RM21.50 (approximately £1 13s). By changing over to welded design and using the cramp table, the labor cost could be reduced to RM8.50 each (about 13s). So the saving in labor cost was RM13 for each pole, or about £1. With overhead costs of 200 per cent the saving in total cost of this single order amounted to:

$1000 \times [13 + (2 \times 13)] =$ RM39,000— or about £3000.

Moreover the 1000 poles proved to be accurately interchangeable, and with hardly any internal stresses. A similar result, showing 40 per cent saving in labor cost, was obtained when an order of 140 lattice girders was carried out, as shown in Fig. 7.

The method of manufacturing welded lattice work by using the "Trifix" cramp table is a very simple one (See Fig. 6). At first the center-lines of the members and their depths are drawn on the layout table consisting of oak planks, by means of pencil or white chalk. Then the chord members are fixed in their exact position by marking pieces "*d*" which can be moved along in specially shaped gliding rails "*c*." Web members (diagonal and vertical rods) are laid out and fixed in position by three taper bolts each screwed into the oak planks. By this method a perfect templet is obtained for assembling any number of similar girders by inserting chords and web members in their exact position.

Then the chord members are held down by special clamps "*f*" and fixing screws "*g*" during the welding operations. Having lifted the clamps "*f*" the completed welded girder may be removed.

In a similar way lattice poles, plate girders, etc., can be assembled and welded together.

The layout table can be arranged to be rotated, thus securing the advantage of being able to carry out welding work while the seams are in a horizontal position with horizontal weld face. By this method welding becomes considerably easier and cheaper.

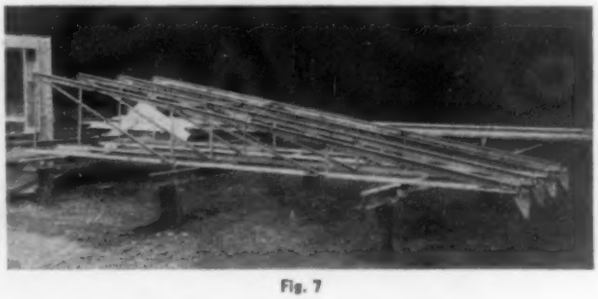


Fig. 7

Oxyacetylene Welding Practice and Technique*

By C. G. BAINBRIDGE,† A. M. I. Mech. E.

THE introduction, a few years ago, of what is now known as the rightward or backward method, revolutionized the principles of oxyacetylene welding. Hitherto, welding had been carried out by the leftward or forward method, limiting the economical application of the process to comparatively thin steel. The rightward method, however, rendered possible the application of oxyacetylene welding on an efficient and economical basis to steel plates or sections of any thickness.

The object of this paper is to put forward the results of practical research on the rightward method, in the form of reliable operating data on the oxyacetylene welding of butt and fillet joints on steel plates and sections upward of $^1/_8$ in. thick.

In order to make subsequent details quite clear it will be as well to describe the leftward and rightward welding methods.

(1) *Leftward Welding.*—The weld is carried out in a leftward direction, the filler rod preceding the blowpipe along the seam. Both filler rod and blowpipe nozzle are held in a vertical plane along the axis of the joint, the blowpipe nozzle pointing in the direction of the unwelded joint. In order to maintain both plate edges and the filler rod in simultaneous fusion, the blowpipe is given a rotary or semirotary motion; the filler rod is either held almost still or follows the path of the welding flame.

The approximate angles of the filler rod and flame are given in Fig. 1.

On thin material the rate of melting of the plate edges can be controlled by the movement of the flame, but on thick material this same movement puts unnecessary heat into the material adjacent to the joint, causing distortion. There is considerable agitation and overheating of the weld-metal, promoting oxidation during its exposure to the atmosphere. The force of the flame tends to push forward molten metal on to the unfused V sides, rendering it difficult to maintain regular penetration and a full, deep bead.

A wide V is necessary in order to accommodate the blowpipe movement and minimize the tendency for the molten metal to flow forward.

(2) *Rightward Welding.*—The weld is carried out in a rightward direction, the blowpipe preceding the filler rod along the seam. As with leftward welding, the blowpipe and filler rod are held in a vertical plane along the axis of the joint, but the blowpipe nozzle points in the direction of the completed weld, and is moved along progressively in the direction of welding, without any sideways or rotary motion; the end of the filler rod is moved in a roughly circular path on the face of the deposited weld-metal.

The tip of the flame-cone is directed toward the bottom of the V, so that the maximum heat of the flame is utilized as much as possible, both sides and the bottom edges of the V and the filler rod melting almost simultaneously.

The angles of blowpipe and rod are shown in Fig. 2.

A comparatively narrow V can be used, requiring less filler metal and resulting in a high welding speed. There is no agitation of the molten metal by the flame, and the

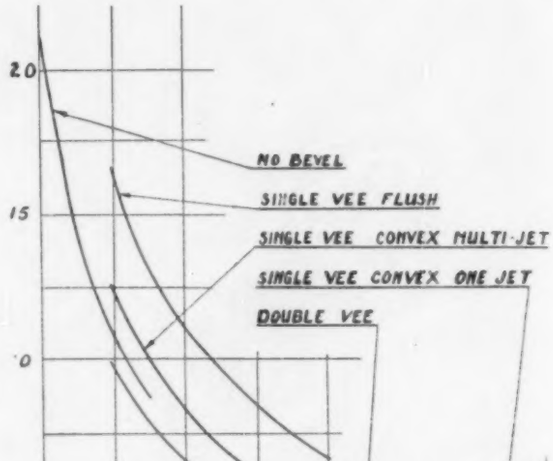


Fig. 5

* Paper presented at Symposium on the Welding of Iron and Steel of the Iron and Steel Institute, London.

† The British Oxygen Co., Ltd.

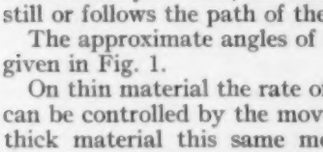


Fig. 1—Leftward Convex V Weld

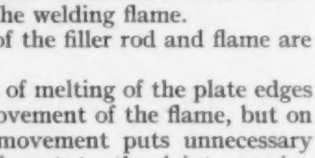


Fig. 2—Rightward Convex V Weld

Fig. 3

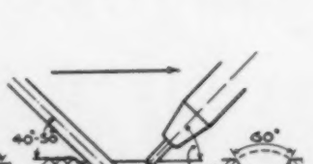


Fig. 4

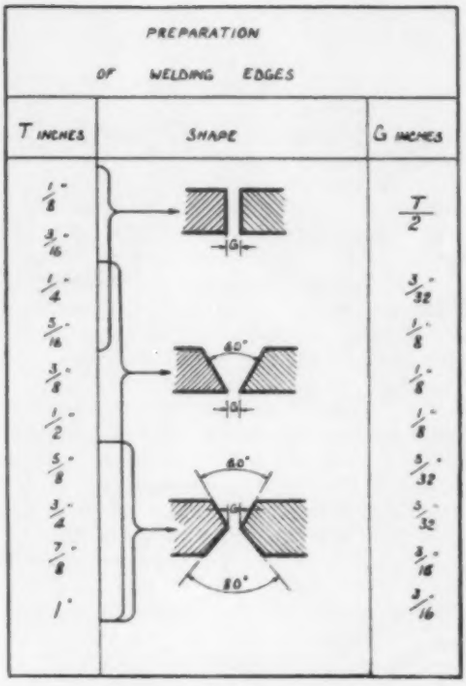


Fig. 6

fusion of the V sides and the welding rod is protected from oxidation by the inner envelope of the flame, which has reducing characteristics. The completed weld cools slowly under the normalizing or retarding influence of the waste outer envelope.

The confinement within the V and the almost complete utilization of the maximum heat of the flame, result in considerable gas economy. The absence of sideways blowpipe motion eliminates heat waste and reduces the heat effect of the metal adjacent to the V, with a corresponding reduction in the tendency to distortion.

There being no tendency to push molten metal forward along the V and no agitation of the molten metal, more powerful blowpipes can be utilized with the rightward method; but the more effective utilization of heat, and the higher welding speed, more than compensate for the greater gas consumption and result in more economical welding.

An important feature of the rightward method is the ease with which the welder is able to control the fusion of the bottom edges of the V; the underbead so formed is equivalent in both appearance and strength to a run of welding on the under side of the weld.

Considerable trial and experiment have established the fact that the leftward method can be used advantageously for welding steel up to about $^1/_8$ in. thick, while for all greater thicknesses rightward welding should be used; upward of $^3/_{16}$ to $^1/_4$ in. the leftward method is uneconomical and produces unsatisfactory results. Below $^1/_8$ in. the rightward method shows little or no advantage.

For normal butt-welding, with two edges of equal thickness, the center line of the blowpipe bisects the V (Fig. 3), the heat absorption of the two edges being equal. For a joint between unequal plate edges the flame is directed toward the thicker edge (Fig. 4) in order to counteract the more rapid heat absorption of that side. The power of the blowpipe is chosen for the thicker section.

Variations of the Rightward Method

(*a*) *Welding without Beveled Edges.*—For the welder of average ability it is not necessary to prepare plate edges to a bevel for underhand flat welds up to $^5/_{16}$ in. thick. Less filler rod is required, enabling a slightly higher welding speed to be achieved, while the cost of preparation is eliminated. Oxygen-cut, or good sheared edges, are quite suitable. The distance between the plate edges is $^1/_2$ *T*.

Unbeveled edges may also be employed for vertical welding on plates up to as much as $^1/_2$ in. thick, where two welders are employed, each working on opposite sides of the plates.

(*b*) *Multi-Jet Welding.*—Consideration of the rightward technique will make it obvious that it is possible to effect a weld just as quickly as the V sides can be prepared for fusion and the welding rod melted. If the plate edges are preheated, it is obvious that at the point of fusion less heat is absorbed from the welding jet in melting the V sides. The remainder of the heat available is utilized in melting the filler rod, resulting in faster welds.

Blowpipes having more than one jet have been in use for some time. Most of these blowpipes employ a normal welding jet, with one or two other jets so disposed as to preheat the V ahead of the weld (see Fig. 17, Plate I), while some have additional nozzles for preheating the welding rod also. In practice it has been found that the blowpipes in which the heating jets are employed for preheating the V only are most satisfactory, it being difficult to control the manual feed of the welding rod through a preheating flame. The preparation of the plate edges and the general technique follow the standard single-jet rightward method, but the angle between the welding rod and plate is smaller. As more heat is available for melting the welding rod, this can be slightly larger than for single-jet welding.

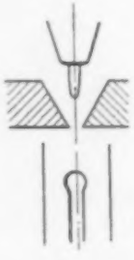


Fig. 7

Multi-jet blowpipes are only slightly more powerful than single jets. The heat is distributed along the V. As there is a considerable increase in speed the cost per foot of weld is greatly decreased. Comparisons of speed are given in Fig. 5.

(*c*) *Flush Welding.*—For many commercial purposes welds do not require to be built-up or have convex weld surfaces, so long as a reasonably strong and pressure-tight weld is effected. For this purpose a special technique producing flush welds (i.e., the weld surface level with the plate) has been developed. The general technique follows the rightward method, but blowpipe and rod angles and blowpipe movement are modified.

Either single- or multi-jet blowpipes can be employed, but best results are obtained with multi-jet blowpipes; the power of the blowpipe should be 1.2 to 1.3 times that of a single-jet blowpipe for similar plate thicknesses. Very high welding speeds are obtained, resulting in a cheap but efficient weld. There is no sacrifice of penetration or under-bead, and tests have indicated that these welds are little inferior to the usual convex surfaced welds.

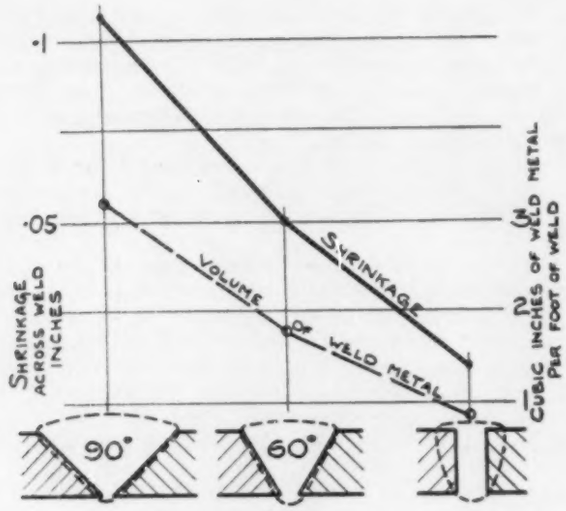


Fig. 8

Preparation of the Welding Edges

Welding bevels should be prepared accurately and uniformly, otherwise the establishment of a definite time or cost schedule is impossible, and the welds will not be uniform.

Figure 6 indicates the joint preparations which have been found most suitable. The limits of economical application of the various types of joints are also indicated.

All bevels should have flat fusion faces, and be prepared to a sharp edge, no flat being left at the bottom of the single V or at the center of the double V.

Up to $^5/_{16}$ in. the edges can be left square; contrary to the usual custom, single-V preparation is recommended for plates up to 1 in. thick, although alternative double-V preparation is shown for plates $^5/_8$ in. to 1 in. thick. Single-V preparation is generally better than double-V, because (*a*) the complete weld is effected from one side, (*b*) it is easier to prepare and costs less; moreover, the risk of porosity and slag inclusions, which are often encountered in the center of double-V welds, is eliminated.

Controlling the Welding Edges

The distance between the edges of the bottom of the V is important; observations of the bottom of the V during welding provides the welder with the best indication of the quality of the weld. Widening of the space into a roughly circular hole, as shown in Fig. 7, indicates fusion of the bottom edges of the V, and the formation of under-bead.

If the gap is too narrow, the sides of the V melt before the bottom, the molten metal running into the bottom of the V and sealing it up, causing the defect of adhesion. To remedy this the blowpipe is raised and much of the effective heat of the flame is lost to the V and spreads over the surface of the material, causing distortion. If the gap is too wide both sides of the V do not melt simultaneously, so that the welding rod is melted into surfaces not ready for fusion, again causing adhesion. To remedy this the blowpipe is lowered and given a side-to-side motion which, although reducing the risk of adhesion, usually causes irregular under-bead, and reduces the welding speed.

It is essential to maintain the edges of the plates in alignment and a uniform distance apart. The edges of short welds can often be controlled by clamps only (see Fig. 18). Long welds must be tacked at frequent intervals, as, although clamps will keep the edges in alignment, they usually do not possess sufficient frictional grip to maintain the necessary space between the edges.

Weld Shrinkage

Shrinkage of the weld-metal and, therefore, the stress set up on cooling, are proportional to the cooling rate and volume of melted metal—or in other words, the cross-sectional area of the weld. Shrinkage is also influenced by overheating of the melted metal, due to agitation during welding and the rate at which it is deposited. It is obviously desirable to reduce the V to the smallest possible angle, as by doing so the filler metal is deposited faster, the fusion is more tranquil owing to the smaller volume of weld-metal that has to be controlled, and there is less shrinkage.

Quite often leftward welding is carried out with a 90° V, but it has been found that 80° is sufficient; rightward welding can utilize a V as small as 60°, and it is recommended that this angle be adopted for all rightward single-V welds. The volume of weld-metal involved in a 60° V is only two-thirds of that in a 90° V, while the width of the weld surface is reduced by almost the same amount.

The cooling stress reaches a maximum when the plates at the side of the weld are not free to move inward in order to accommodate the shrinkage. Some idea of the proportion of the cooling stress can be gaged from Fig. 8, indicating the weld shrinkage on three types of welds.

Filler Rod

Apart from the fact that the composition of the rod affects the melting temperature, the rate of deposition is proportional to the square of the diameter of the welding rod. In proportion to its size the rod also exercises a cooling action on the molten metal.

A small rod melts quickly and insures a heavy top bead; if it melts too fast it may result in adhesion in the

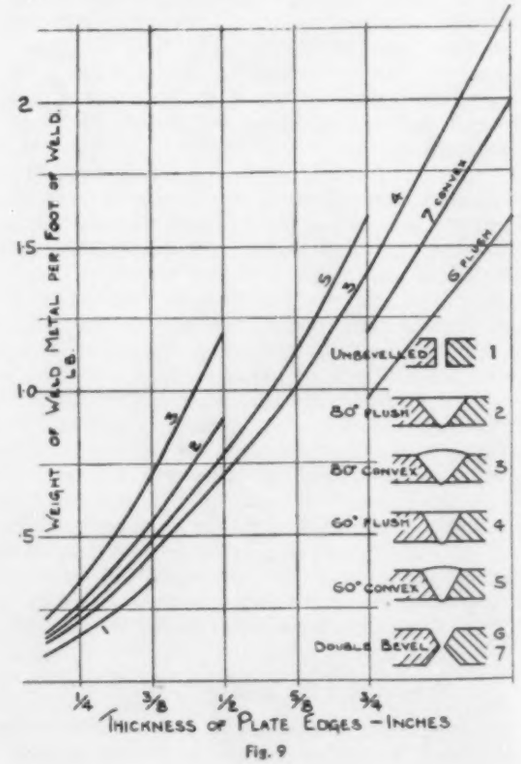


Fig. 9

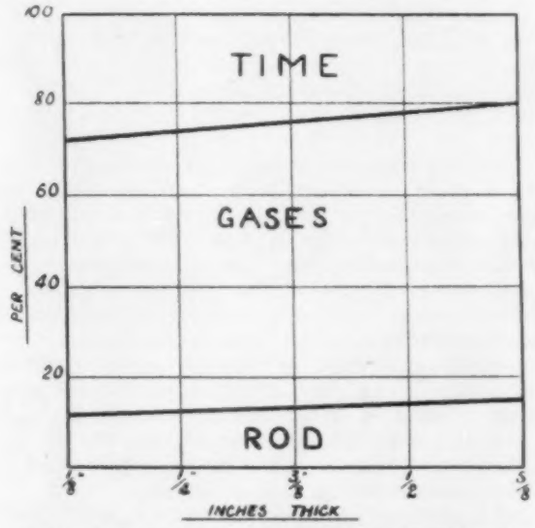


Fig. 10—Proportions of Time, Gases and Welding Rod for Rightward Welding

bottom of the V owing to insufficient time being available for thorough fusion of the V sides. A large rod melts slowly and cools the molten puddle, causing rapid solidification and only a small top and under-bead.

For single-run welding the diameter of the rod bears the following relation to plate thickness: $D = {}^1/_2T + {}^1/_{32}$ in. For welding without a bevel the diameter of the rod should be ${}^1/_2\ T$. The different quantities of weld-metal required for various types of welds are given in Fig. 9. Welding rod is deposited at a rate varying from $2^1/_2$ to 5 lb. per hr., according to thickness, or 1 lb. per 14 or 15 cu. ft. of acetylene.

Welding Speed

The rate of welding for different types of underhand butt welds is shown by the curves in Fig. 5. The welding speed is represented by C/T, where T represents the plate thickness in eights of an inch and C is a constant which varies for different techniques; some values of C for rightward welds are as follows:

For single-jet single 60° V convex welds	$C = 20$
" multi-jet " " " "	$C = 25$
" " " " flush "	$C = 33$
" single-jet unbevelled convex "	$C = 21.5$

Short welds can be made at higher speeds than long welds. Welding in the open air may be as much as 10 or 15 per cent slower than similar welding done in a workshop.

The cost of rightward welding in pence per foot run varies from $1.2T^2$ for steel ${}^3/_{16}$ in., to T^2 for plates ${}^3/_4$ in. thick. The proportions of cost of time, gases and welding rod are given in Fig. 10. It will be noticed that the gas cost remains fairly constant throughout the thickness range.

The Welding Flame

The blowpipe for rightward welding can be a little more powerful than would be used for leftward welding.

Fig. 11

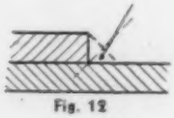


Fig. 12

The blowpipe power in cubic feet of acetylene per hour for any thickness of steel between ${}^1/_8$ in. and ${}^3/_4$ in. thick is represented approximately by $12T + 8$ (T = thickness of steel plate in eights of an inch).

Less powerful blowpipes result in a heavy reinforcement or convex weld surface, giving rise to waste of weld-metal and slow welding speed. More powerful blowpipes render it difficult to achieve a convex weld surface and produce flush welds.

A fairly soft flame with a parallel round-ended cone is best; the diameter of the cone depends upon the diameter of the nozzle orifice, but the cone length depends on the gas speed and does not increase proportionally with the plate thickness; a cone length between $11^1/_2$ and $12^1/_2$ mm., using generated acetylene, represents a mixed gas speed of between 360 and 420 ft. per sec. Higher gas speeds produce longer cones, but this indicates a waste of gas, as the heat given off from the upper part of the sides of the cone cannot be usefully employed.

Fillet and Corner Welding

Owing to the difference in the rate of heat absorption of the two fusion faces of a fillet weld, a modified technique is employed. If a single jet is used the center line of the jet does not bisect the joint angle but the nozzle is directed toward the side which absorbs heat most rapidly.

Figures 11 and 12 depict two types of fillet weld. The approximate position of the blowpipe flame is indicated by arrows.

For single-sided fillets the two-flame blowpipe is very useful, as the preheating jet can be directed toward the side which is absorbing heat rapidly (Fig. 13).

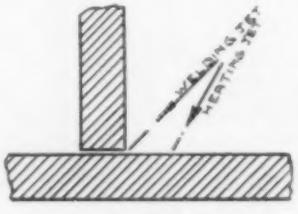


Fig. 13

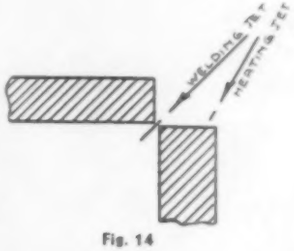


Fig. 14

Fig. 15

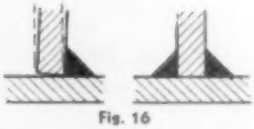


Fig. 16

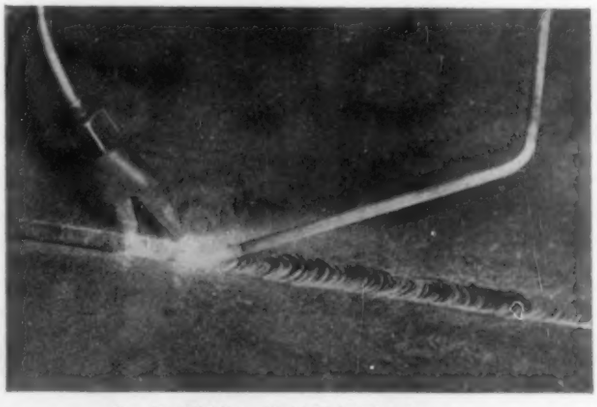


Fig. 17—Welding with Multi-Jet Blowpipe

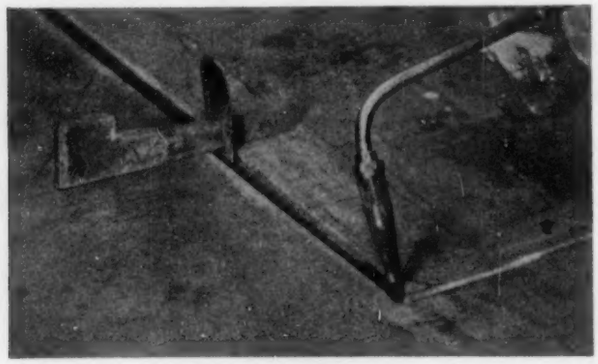


Fig. 13—Edges Clamped for Welding

For a corner weld between two equal plates the blowpipe center line bisects the V between the edges, but if the plates are unequal the flame is directed toward the thicker section. In the latter case the two-jet blowpipe is again useful, as the preheating flame can compensate for the greater heat absorption of the thicker edge (Fig. 14).

The joint can be close, as depicted in Fig. 15, or a small space can be left. Generally, for practical considerations, close joints are preferable. The abutting plate edge of a fillet weld should be left square and not beveled.

Where two fillets are required on opposite sides of an abutting plate or section, they should be made simultaneously, employing two blowpipes. Smaller blowpipes can be used. Heating and cooling are equal, so that there is no tendency for the angle between the joints to be distorted (Fig. 16). Small opposite intermittent fillets cause less distortion than large intermittent staggered fillets and can be put down in less time.

Generally, most fillet and corner welds, where both sides must be sealed, are best dealt with by using two welders operating together, making either equal or unequal welds according to the type of joint, the size of the fillet being controlled by the blowpipe power and the size of the welding rod.

Table 1 gives typical welding data for rightward single-V convex welds.

Table 1—Welding Data for Rightward Single-V Convex Welds. T = thickness of plate in eighths of an inch

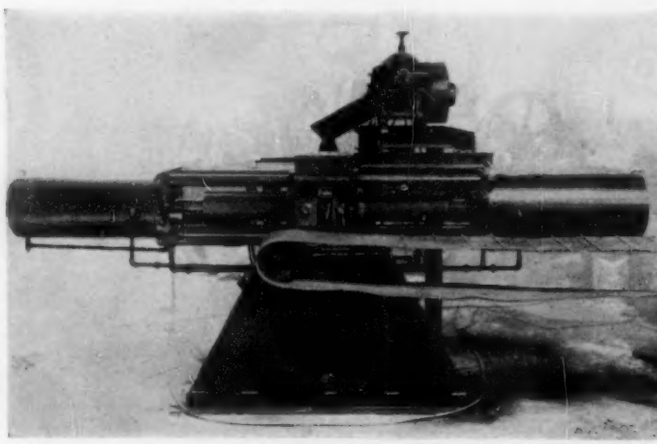
Plate Thickness, In.	Blowpipe Power, Cu. Ft. of Acetylene per Hr. $12T + 8$	Welding Rate, Ft. per Hr. $\frac{20}{T}$	Welding Rod Consumed, Ft. per Ft. of Weld, Size = $\frac{T}{2}$ to $\frac{T}{2} + 1/32$ in.					
			1/8	5/32	3/16	7/32	1/4	5/16
1/8	20	19–21	1.2	...	..	..	...	..
3/16	26	14–16	2.5	1.6	..	..	...	..
1/4	32	10–11	...	3.5	2.5	..	...	..
5/16	38	7–8	...	...	3.75	2.75	...	..
3/8	44	6–7	...	...	5.2	3.8	...	...
1/2	56	4.5–5.5	...	...	..	6.25	4.75	..
5/8	68	3.75–4.25	...	...	..	9.25	7	..
3/4	80	3–3.25	...	...	..	..	10	6.25
1	105	2–2.25	...	...	..	..	12	7.75

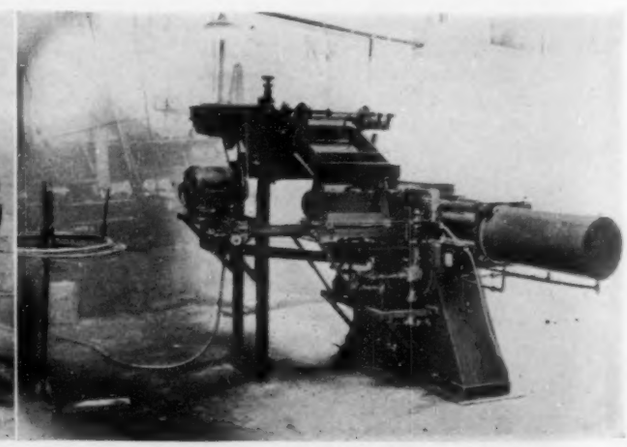
Extruding Machine

By C. J. HOLSLAG†

The illustrations indicate an extruding machine which takes the wire from the coil, entirely automatic, straightens, cuts, extrudes at a speed of 100 feet per minute. For heavy production, a separate straightening and cutting machine or a battery of them is better. The completed straightened and cut wire is loaded into a hopper on the welding machine and the extrusion is automatic from that point on.

† Electric Arc Cutting & Welding Company.





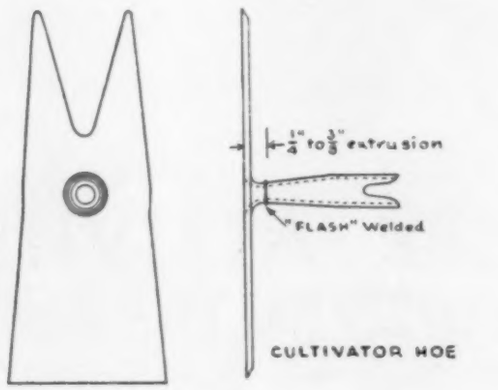
Flash Welding Pipe or Tube to Flat Surfaces

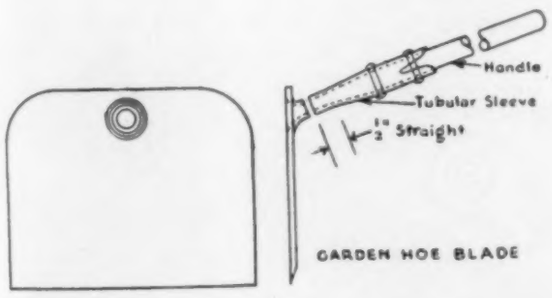
By M. L. ECKMAN†

THIS method of production welding can be used to advantage on a good many products. Typical examples are the garden and cultivator hoes shown here. It is faster and cheaper than riveting or forging a flat piece to the back of the blade and results in a much lighter implement without sacrificing strength.

The tubular section can be attached at right angles as in the case of the cultivator hoe or it can be attached at an angle as shown in the garden hoe diagram. In either case the procedure is the same.

The blade is pierced and extruded to form a ferrule $^1/_4$ in. to $^3/_8$ in. long and of the same diameter as the tube end. When the ferrule and tube end are flash welded,





they make a single unit of the blade and handle. As is usually the case with resistance welding, the welded part is as strong or stronger than the parent metals so there is no danger of failure at this point. The handle can be formed from pipe, tube or sheet metal rolled into tubular form.

The welder commonly used for this type of work is available in the proper stock capacity and with the necessary dies and jaws for handling a wide variety of work.

† Research Engineer, Thomson-Gibb Electric Welding Company.

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WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

Educational Committee

At the meeting of the Board of Directors held during the Annual Meeting of the Society the President was authorized to appoint an Educational Committee whose function it would be to cooperate with the Membership Committee and Section executives in planning activities of general interest to members. Every member of the Society who has some special ideas on the subject is invited to send in his suggestions to Secretary M. M. Kelly.

Employment Bureau

At the meeting of the Board of Directors held on April 24th opinion was expressed that the Sections might render a valuable service to industry by the establishment of local employment service bureaus. Through the formation of Committees, the necessary surveys could be conducted and arrangements made whereby,

1. Employers would notify the Bureau whenever they found it necessary to let go competent men, furnishing with names, their qualifications and ratings.
2. Employers would apply to the Bureau when in need of assistance, and
3. The unemployed might register with the Bureau furnishing complete record of their experience. The office of the local Section would be the logical point of contact.

It was believed also that the Sections through their Officers and influential members could bring about greater interest in the Section affairs particularly its meetings, by inducing officials of the large corporations in their vicinities to actually participate in the Section meetings, either by giving talks or presiding at the meetings.

Nitrides in Fusion Welding

A report on the formation of Nitrides in Fusion Welding by Dr. D. Seferian has been issued by Institut de Soudure Autogene, 32 Boulevard de la Chappelle, Paris.

Metal Spraying

The Metallizing Company of America, Inc., with their general offices at Los Angeles, California, have prepared a four-page pamphlet covering the uses of metal spraying equipment on general maintenance applications. This pamphlet has photographs of metallizing jobs that have been in service a number of years.

Welded Piping for Buildings

The Air Reduction Company has just issued an attractive pamphlet entitled "The Facts about Welded Pipe for Buildings." It is designed to show the advantages of the use of a method of welding pipe for piping installations.

The booklet itself was planned particularly to interest architects and heating engineers, but building and plant executives responsible for piping installations or the maintenance thereof will find much to catch and hold their attention.

Well illustrated with photographs of typical installations, the booklet is so arranged as to permit the reader to quickly grasp the salient facts about the advantages of Aircowelding.

Third International Rail Assembly

The Third International Rail Assembly under the auspices of the Hungarian Association for Testing Materials will be held in Budapest September 8–12, 1935. A number of papers on the subject of Welding will be presented.

Annual Report, American Bureau of Welding

The American Bureau of Welding was organized simultaneously with the AMERICAN WELDING SOCIETY and has served as the research branch of the Society and also as the welding branch of the Engineering Division of the National Research Council. It also includes representatives from a considerable number of other engineering and scientific societies. The purpose of this separate organization was: (1) to enlist the hearty cooperation of other technical and scientific agencies which seemed peculiarly desirable because of the wide variety of phenomena involved in the welding art and the large number of both technical and scientific organizations naturally interested in these phenomena; (2) in order to make sure that the output of the Bureau would be as free as possible from all suspicion of commercial bias.

In the beginning the work of the Bureau included not only all of the research in the welding field, but also the work of standardization. Gradually the work in this latter field was taken over by AMERICAN WELDING SOCIETY and most of the research projects initiated by the Bureau and supported cooperatively by industry were completed. The only cooperative project uncompleted at the present time is that handled by our Structural Steel Welding Committee, which still has a fund of about six thousand dollars at present in the hands of the National Research Council, which has been from the beginning the repository for similar funds.

Inasmuch as the only projects for which financial support could be obtained from industry were those promising reasonably prompt returns of a practical nature and inasmuch as industry seemed disinclined to contribute to the more fundamental types of research in this field, our Fundamental Research Committee was organized to see what could be done without much financial assistance.

Under the direction of its Chairman, Mr. H. M. Hobart, and its Secretary, Mr. William Spraragen, the work of this committee has grown to very large proportions as indicated by Mr. Hobart's report given below. A brief statement is also given below of the recent work of the Structural Steel Welding Committee under the direction of Mr. L. S. Moisseiff.

Some idea of the extent of the work of these two committees can be obtained from the following list of reports published during the past year.

Fundamental Research Committee

Report by Mr. H. M. Hobart, Chairman of the Committee

The annual meeting of the Fundamental Research Committee on Welding was held on the evening of October 2, 1934, in connection with the Fall Meeting of the American Bureau of Welding. In attendance were 23 university professors and 19 other interested people, some from industrial laboratories. The professors described their researches, and discussions followed. Such occasions have been held annually for four years. On this, as on the three former occasions, the meeting was made possible by an NRC grant to cover the traveling expenses to the meeting of the professors in attendance.

The results of their researches are reported in the JOURNAL of the AMERICAN WELDING SOCIETY, there being, recently, some eight or ten such reports annually. There are 64 university professors associated in this welding research work. Occasional grants-in-aid are provided by NRC. Thus, in 1934, such a grant was made to Union College and enabled Dr. M. F. Sayre to undertake a library research on bend tests for welded joints. Among several other undertakings reported last October was Mr. Spraragen's Progress Report on "Impact Resistance of Welded Joints."

It is hoped to constitute authoritative sub-committees by groups of these professors who are working on subjects bearing close relation to one another. It will be of great value to turn to these specialized groups when in need of information or tests in particular fields.

Thus (1) at eight university laboratories various investigations are being made relating to metallurgical aspects of welded joints, (2) at three, ductility of welded joints is being studied, (3) seven laboratories are investigating heat treatment and methods of stress relieving, (4) corrosion tests and corrosion fatigue are being investigated at four laboratories, (5) at six laboratories the structural problems of welded joints are being investigated, (6) four laboratories are making photoelastic investigations, (7) the welding of ferrous and non-ferrous alloys and non-ferrous metals are the subjects at 6 other laboratories.

However, in a good many instances, only one laboratory is engaged on some important field which could be profitably subdivided among several research workers. Many urgent, and at present insufficiently understood, welding problems are not being investigated anywhere.

We have no financial resources for this work. Sometimes we have been able to arrange for some financial support for a particular research; sometimes the professor or university does this locally. On two or three occasions, A. W. S. Sections have made local research grants from their accumulated reserves. Sometimes industry has helped in specific cases. Very often indeed, industry has helped by loaning apparatus and by making up welds.

But the greatest need is for office assistants to keep in close touch with the professors; to supply them with information; to suggest progress reports and to consider them in detail when received; to call attention to urgently needed researches and to follow up all these things. It is especially necessary to give to the professors real proof that their efforts are valued and that they are doing work which is vital to the sound development of the welding industry.

But at present the Secretary and Chairman cannot give to the project one-tenth of the attention its importance deserves. Either, in twenty minutes per day, could impart to an assistant the instructions necessary to greatly assist the undertaking in these various ways. Even with this lack of financial aid the committee every year does more work and of greater value. With funds and assistance, it could do much more and do it much more efficiently.

Structural Steel Welding Committee

For the most part the activities of this Committee have been confined to an investigation on Seat Angles in cooperation with Lehigh University. A comprehensive report dealing with physical tests and photoelastic studies was published in the February issue of the JOURNAL. Investigations are now under way dealing with comparative tests of fillet welds in narrow and wide plates subject to bending and tension. A program for additional work will be presented at the meeting of the Committee on April 25th.

Published Reports

During the year there has been published under the auspices of the Committees of the American Bureau of Welding the following reports:

Tensile Tests of Welded and Riveted Structural Members—R. P. Davis and G. P. Boomsliter, April 1934.

Welding of Structural Nickel Steel—W. L. Warner, June 1934.

The Nature of the Bond in Bronze-Welding—A. A. Jackman, July 1934.

An Examination of Welds Made under Field Conditions for High-Pressure, High-Temperature Steam Station Piping—A. E. White, D. H. Corey and C. L. Clark, September 1934.

Notes on the Fatigue Testing of Welds—J. H. Zimmerman, September 1934.

Historical Developments and Future Possibilities of Welding—D. S. Jacobus, October 1934.

Resistance Welding of Thin-Gage Duralumin—N. F. Ward, December 1934.

Some Measurements of Residual Stresses in Arc-Welded Steel Plates—R. E. Jamieson, December 1934.

An Investigation of Welded Seat Angle Connections, by Inge Lyse and Norman G. Schreiner, February 1935.

A Photoelastic Study of Bending in Welded Seat Angle Connections, by Inge Lyse and Douglas M. Stewart, February 1935.

Corrosion-Fatigue Study of Welded 18:8 Stainless Steel, by W. E. Harvey, A. J. Ciastkewicz and F. J. Whitney, Jr., January 1935.

Effect of Peening on Physical Properties of Welds and Stress Relief, by O. M. Harrelson, Preprint of Fall Meeting Papers.

Reorganization of the American Bureau of Welding

Owing to the fact that the National Research Council finds it no longer possible to sponsor the work of the Bureau and to contribute to its support as it has in the past, and owing to the fact that most of the agencies now cooperating in the work of the Bureau are inactive in that connection, there seems to be no good reason for continuing the present form of organization as such. It has been proposed therefore to make the present work of the Bureau an integral part of the activities of the AMERICAN WELDING SOCIETY.

The Committee on Reclassification of Membership of the AMERICAN WELDING SOCIETY considered this whole matter very carefully and recommended that the present Bureau be abolished and that the Society appoint a welding research committee on which would serve the chairmen of the research committees (Fundamental and Structural), a representative of the National Research Council, a representative of Engineering Foundation and five others to be appointed by the president. The committee would have the same status as other standing committees of the AMERICAN WELDING SOCIETY.

This matter was duly considered by the Board of Directors of the AMERICAN WELDING SOCIETY and while the Board generally approved this recommendation, it felt it desirable to ascertain the wishes of the National Research Council and to permit a discussion of this whole situation by members of the American Bureau of Welding.

After due deliberation the National Research Council indicated that it was necessary to limit its expenditure in every possible way, which made it impossible for them to remain a joint sponsor and to contribute toward the maintenance of the American Bureau of Welding as in the past. On behalf of the National Research Council, Dr. Bowman expressed his regret that it was necessary to make such a decision and indicated that the Council appreciates the high quality of the work done by the Bureau.

This matter was considered at a meeting of the American Bureau of Welding on April 25th. That body voted to disband and to recommend to the AMERICAN WELDING SOCIETY the appointment of a Research Committee and the transference of the two sub-committees on (a) Structural Steel and (b) Fundamental Research.

Later in the evening of the same day the Board of Directors voted to take over the sponsorship of the present American Bureau of Welding and the two above-mentioned Committees.

C. A. ADAMS
Director

SECTION ACTIVITIES

CHICAGO

The following officers were elected by the Chicago Section:

Chairman—D. C. Wright
Vice-Chairman—Albert Reichmann
Sec.-Treas.—F. L. Spangler
Directors for 3 years—Gale Adams
R. G. Mason
R. E. McFarland
E. L. Quinn

Director to represent Chicago Section at New York Meetings of Society—C. J. McGregor.

MILWAUKEE

The newly organized Milwaukee Section held its last meeting of the Spring season on May 28th at the Milwaukee School of Engineering, 1020 North Broadway. Mr. Robert Holt of Chicago Steel & Wire Co., gave a lecture and showed moving pictures on "Metal Transfer in Welding." Mr. Hubert O. Quartz of Allis-Chalmers Mfg. Co. spoke on "Practical Aspects of Heavy Welding" and showed slides. Mr. Walther Richter of the A. O. Smith Corp. gave an illustrated talk on "Measuring Arc Voltages."

At this meeting the following Board of Directors was appointed:

2 years—R. W. Sternke
W. E. Crawford
Gustave Johnson

1 year—R. E. Boeck
A. F. Meyer
L. J. Larson.

SAN FRANCISCO

The regular monthly meeting of this Section was held on June 21st at the Athens Athletic Club, Oakland. Mr. S. H. Edwards, Material Engineer for the Standard Oil Co., spoke on "The Effect of Temperature on Stresses in Metals from Casting, Welding, Heat-Treating and Heat-Flow in Furnaces."

A very interesting discussion followed and the rest of the meeting was given over to a discussion on the Qualification of Welding Operaters, expenses incurred therein and possible ways and means of reducing these expenses.

Fundamental Welding Researches

EDITOR'S NOTE: *It is proposed to publish, from time to time, in the* JOURNAL, *brief progress reports of the investigations in Fundamental Research in Welding. While most of these items will relate to the work of the Fundamental Research Committee and the Structural Steel Welding Committee of the American Bureau of Welding, nevertheless, all investigators are encouraged to give the editor news items of this nature which may be included in this column.*

Copper Welding Research

R. R. Seeber, Mechanical Engineering Department, Michigan College of Mining and Technology—"We made a review of the literature on welding of copper by the long carbon arc method and by the oxy-acetylene method.

"From such library research we outlined methods of procedure for both arc and gas welding of copper, covering such points as manipulation of flame, length of arc or cone, spacing, type and size of carbon in rod, spacing, chamfering, clamping and preheating. We are investigating under arc welding of copper; current and voltage characteristics, rod size, material, spacing, effect of chamfer angle and speeds upon strength of weld; effect of heating upon strength and hardness of parent metal. All welds are tested to destruction and data taken for tables showing strength before and after welding, and other results. Under gas welding we are investigating speed of welding, size of tip and pressure to use for thickness of plate welded, preheat required, filler rod size and effect of various rod materials on weld, effect on parent metal of preheat and welding heats, properties of weld under tensile tests.

"Progress is necessarily slow. However, to date there have been welded and tested 141 specimens welded by oxyacetylene, 30 welds yielding 182 specimens by the long carbon arc process. Complete and accurate data have been taken from which considerable information and tables may be worked up."

Electric Welding Tried on Tanker

The following item appears in the Christian Science "Monitor" dated June 10th:

"Jarrow, Eng.—Welding has taken the place of rivets in an ocean-going ship of considerable size—the oil tanker Moira, launched here April 30th.

"The Moira is 245 feet long and 2240 tons dead weight. The electric welding construction in place of rivets gives the advantage of increased carrying capacity, and the smooth inner surfaces of the tanks make for simplicity in cleaning them out.

"A representative of the Norwegian firm for which the Moira has been built stated after the launching that this firm would go in for all-welded vessels of increased size."